Overview of the Crew Launch Vehicle Upper Stage

Joan Funk

Presented to the Materials and Structures for Extreme Environments meeting of the Constellation University Institutes Project

The overview begins with the bold vision for space exploration set out by President Bush in 2004. A brief description of the proposed systems architecture is presented along with an animation showing the various stages and phases of a mission. The overview concludes with latest roadmaps for the Upper Stage.

National Aeronautics and Space Administration

Constellation Systems Launch Vehicles Project

Overview of the Crew Launch Vehicle Upper Stage

Materials and Structures for Extreme Environments Meeting

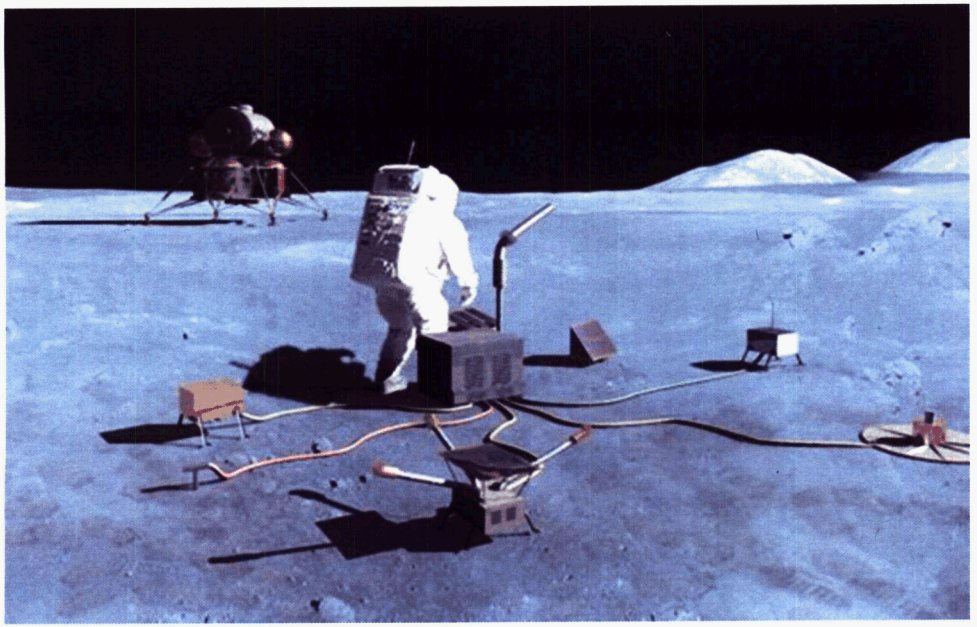
Joan Funk

June 6, 2006

www.nasa.gov

A Bold Vision for Space Exploration

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration



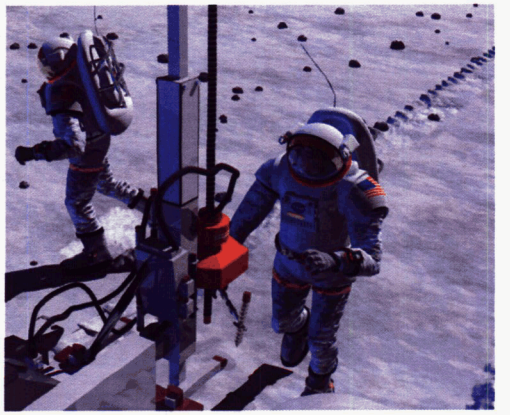
"It is time for America to take the next steps.

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time"

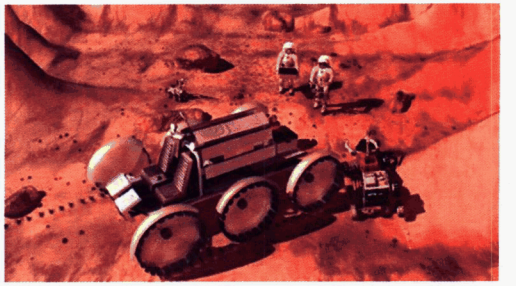
President George W. Bush – January 14, 2004

The Moon – the 1st Step to Mars and Beyond....

- **Gaining significant experience in operating away from Earth's environment**
  - Space will no longer be a destination visited briefly and tentatively
  - "Living off the land"
  - Human support systems



- **Developing technologies needed for opening the space frontier**
  - Crew and cargo launch vehicles (125 metric ton class)
  - Earth ascent/entry system – Crew Exploration Vehicle
  - Mars ascent and descent propulsion systems (liquid oxygen / liquid methane)

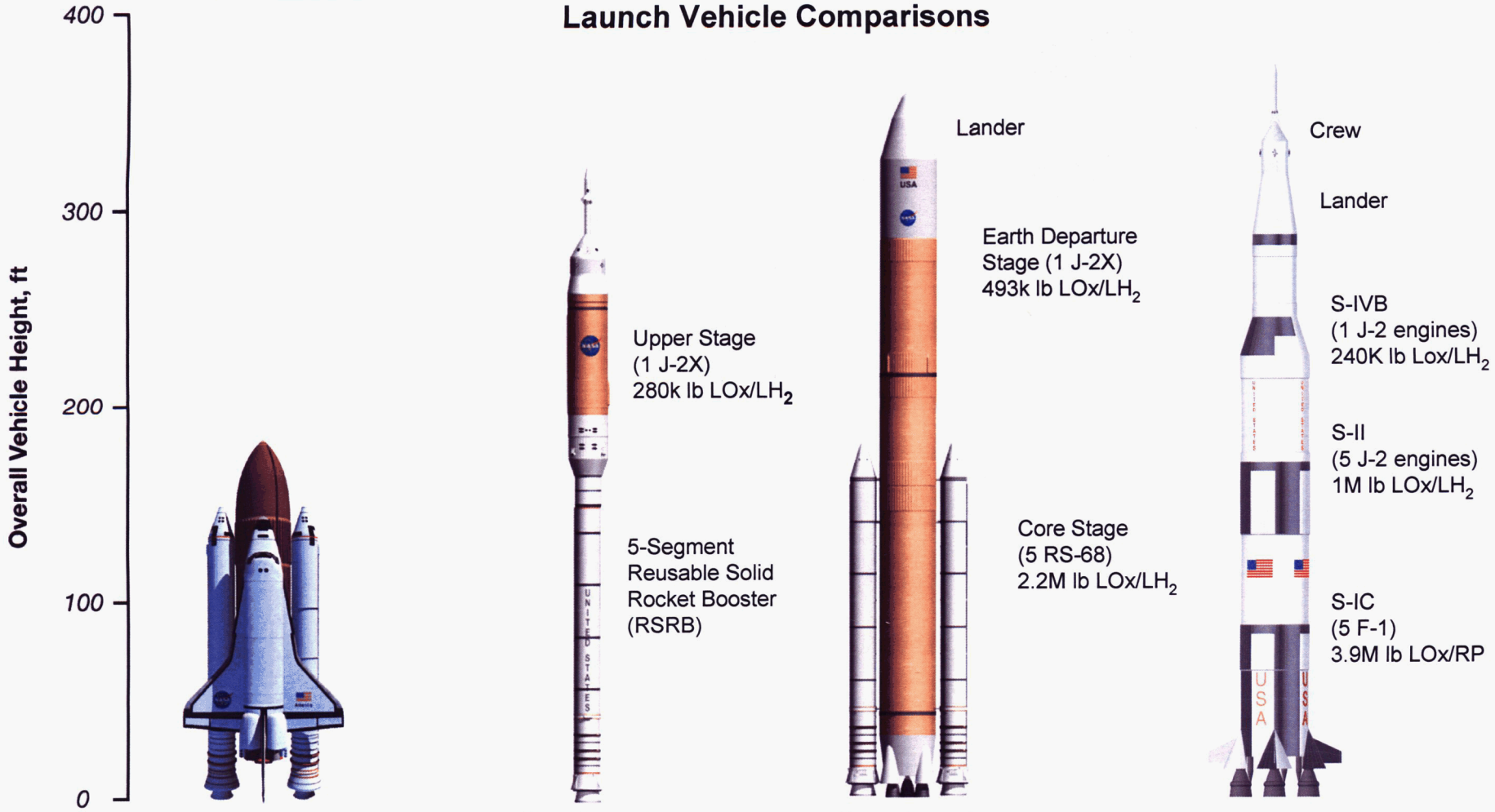


- **Conduct fundamental science**
  - Astronomy, physics, astrobiology, historical geology, exobiology

Next Step in Fulfilling Our Destiny As Explorers

Building on a Foundation of Proven Technologies

Launch Vehicle Comparisons



Space Shuttle

Height: 184.2 ft
Gross Liftoff Mass: 1.7M lb

55k lbm to LEO

Crew Launch Vehicle

Height: 321 ft
Gross Liftoff Mass: 2.0M lb

55k lbm to LEO

Cargo Launch Vehicle

Height: 358 ft
Gross Liftoff Mass: 6.4M lb

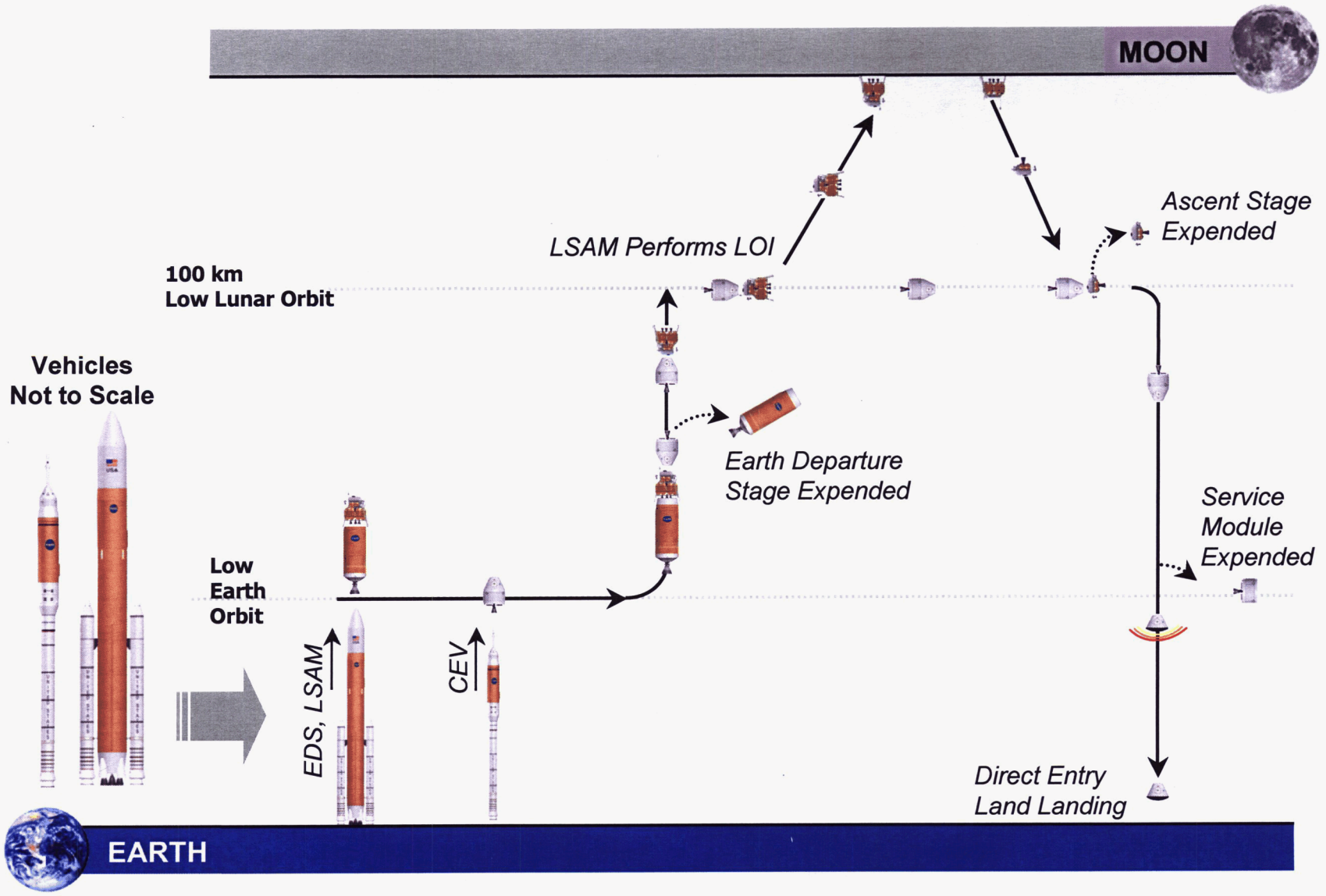
121k lbm to Trans-Lunar Injection (TLI)
147k lbm to TLI in Dual-Launch Mode with CLV

Saturn V

Height: 364 ft
Gross Liftoff Mass: 6.5M lb

121k lbm to LEO

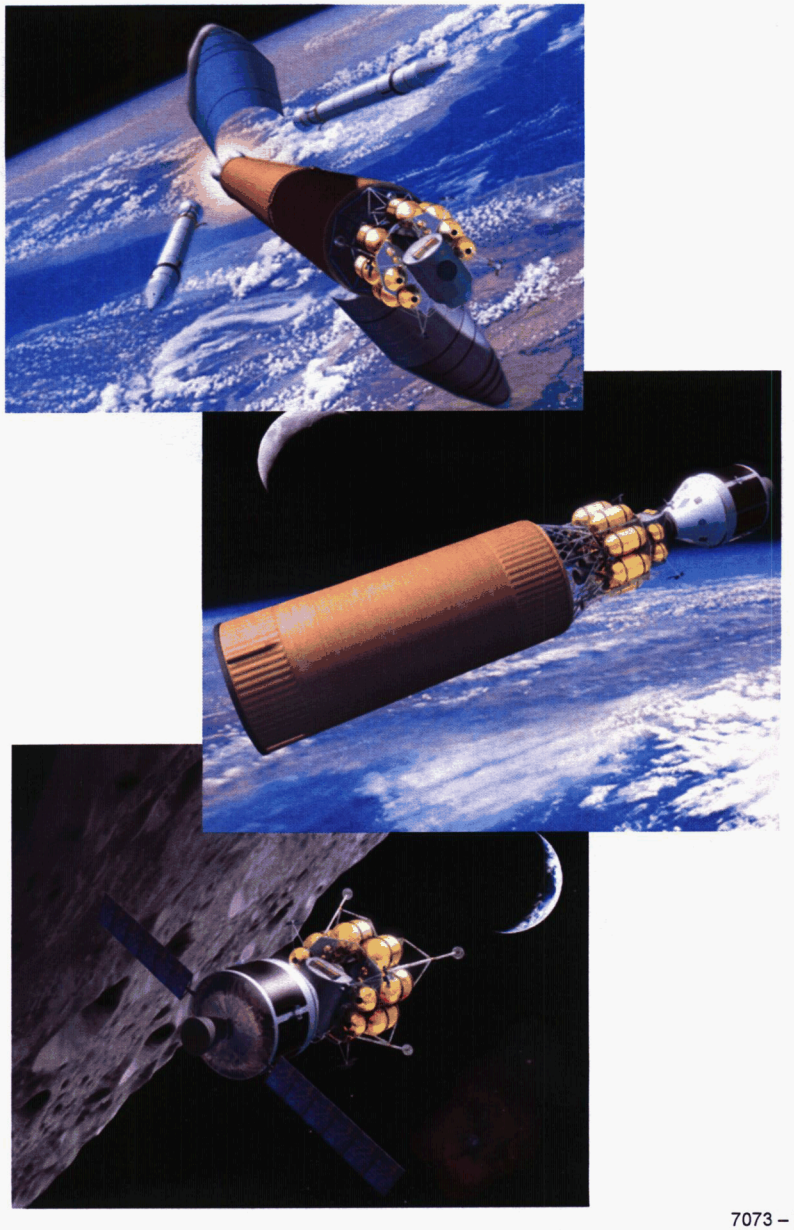
"1.5 Launch" Earth Orbit / Lunar Orbit Rendezvous



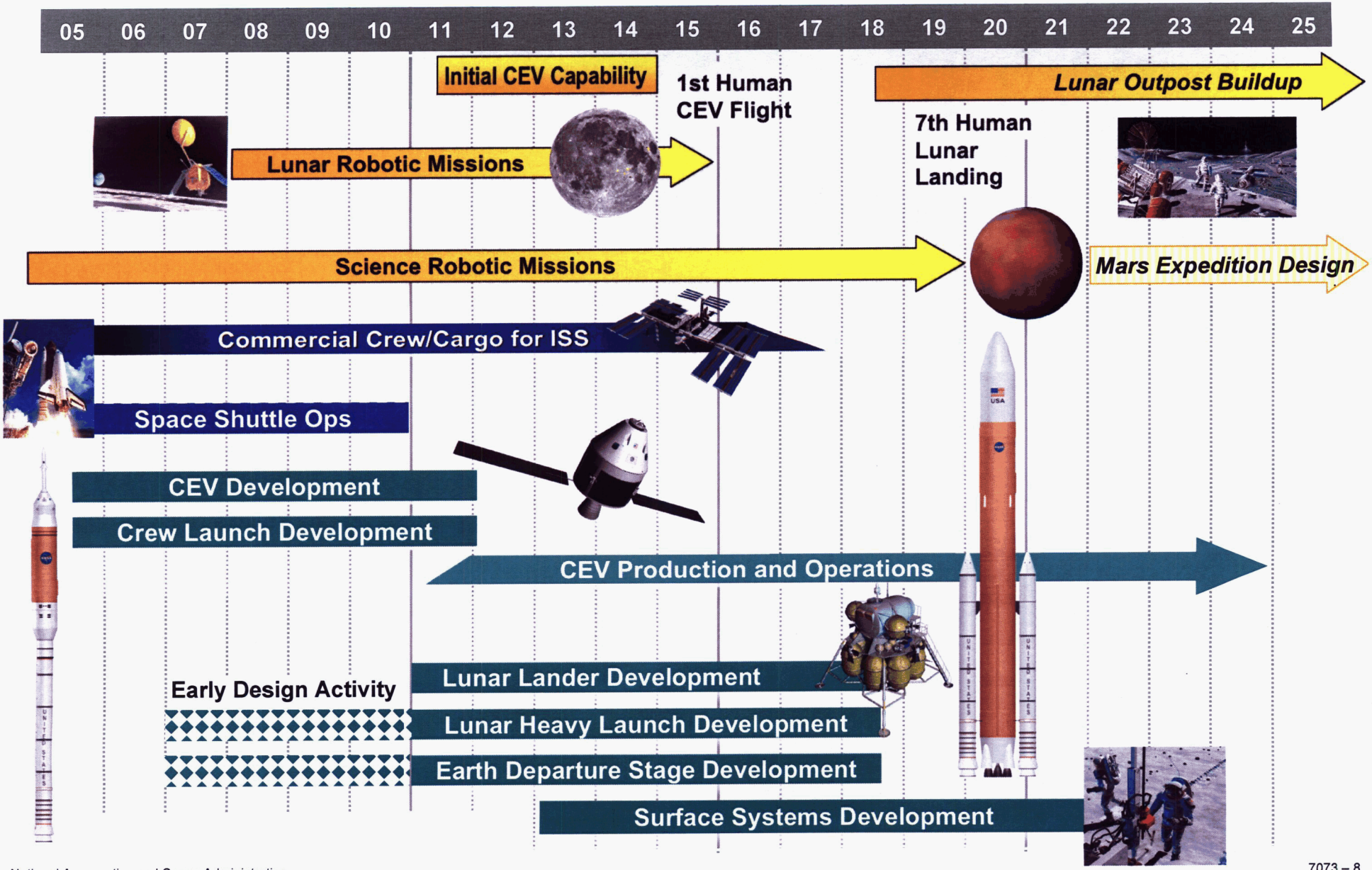

UNITED STATES

Design Philosophy for Mission Success

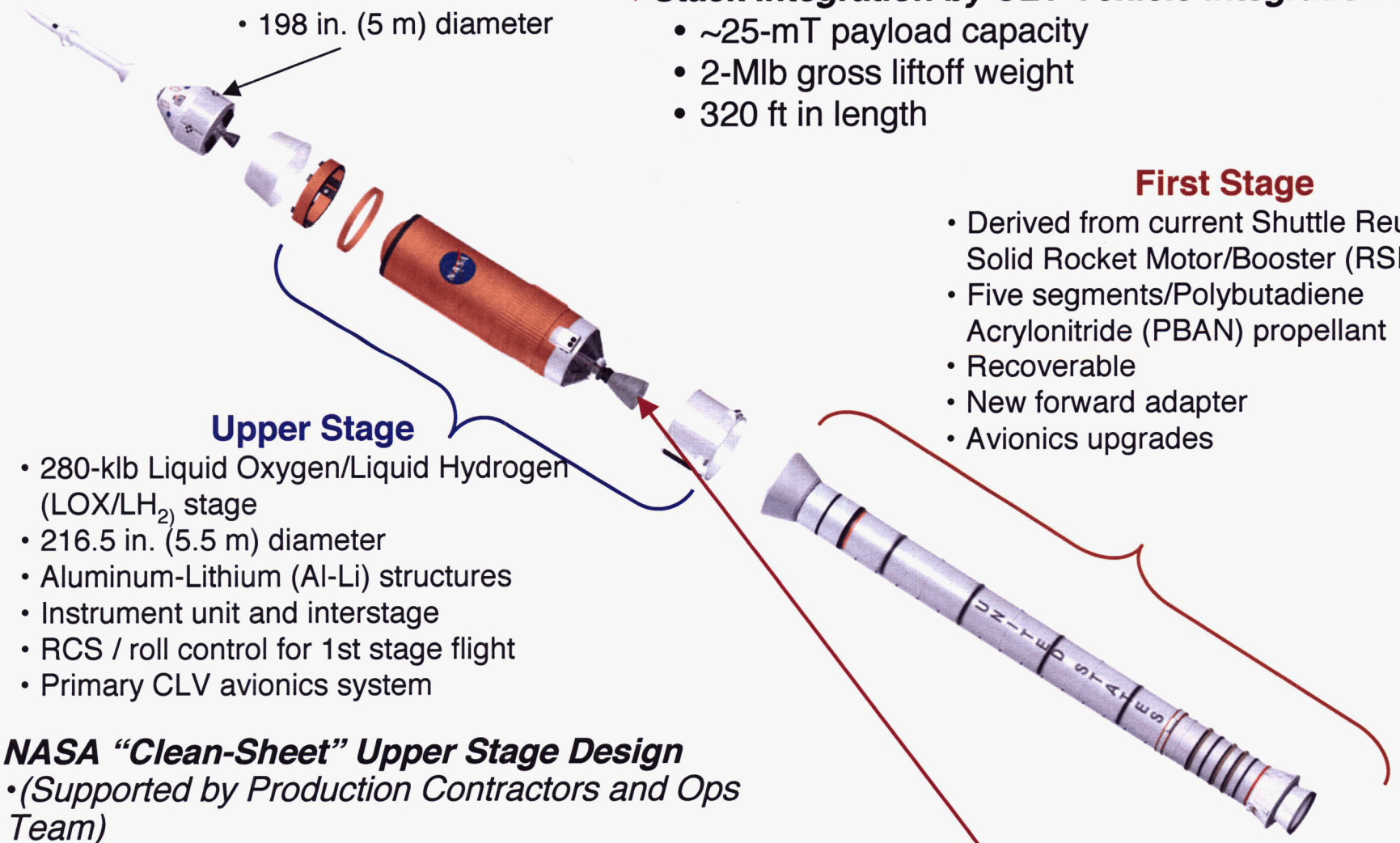
- **Keep it simple.**
  - Minimize complexity and interactions.
  - Simplify interfaces.
  - Make it robust.
- **Focus on reliability, maintainability and supportability early to improve safety and reduce operations costs.**
- **Apply validated engineering tools, models, and data to new vehicle configurations.**
- **Apply Lessons Learned**



NASA's Exploration Roadmap



Upper Stage Overview



CEV

- 198 in. (5 m) diameter

♦ ***Stack Integration by CLV Vehicle Integration Ofc.***

- ~25-mT payload capacity
- 2-Mlb gross liftoff weight
- 320 ft in length

First Stage

- Derived from current Shuttle Reusable Solid Rocket Motor/Booster (RSRM/B)
- Five segments/Polybutadiene Acrylonitride (PBAN) propellant
- Recoverable
- New forward adapter
- Avionics upgrades

Upper Stage

- 280-klb Liquid Oxygen/Liquid Hydrogen ($LOX/LH_{2)}$ stage
- 216.5 in. (5.5 m) diameter
- Aluminum-Lithium (Al-Li) structures
- Instrument unit and interstage
- RCS / roll control for 1st stage flight
- Primary CLV avionics system

♦ ***NASA "Clean-Sheet" Upper Stage Design***

- *(Supported by Production Contractors and Ops Team)*

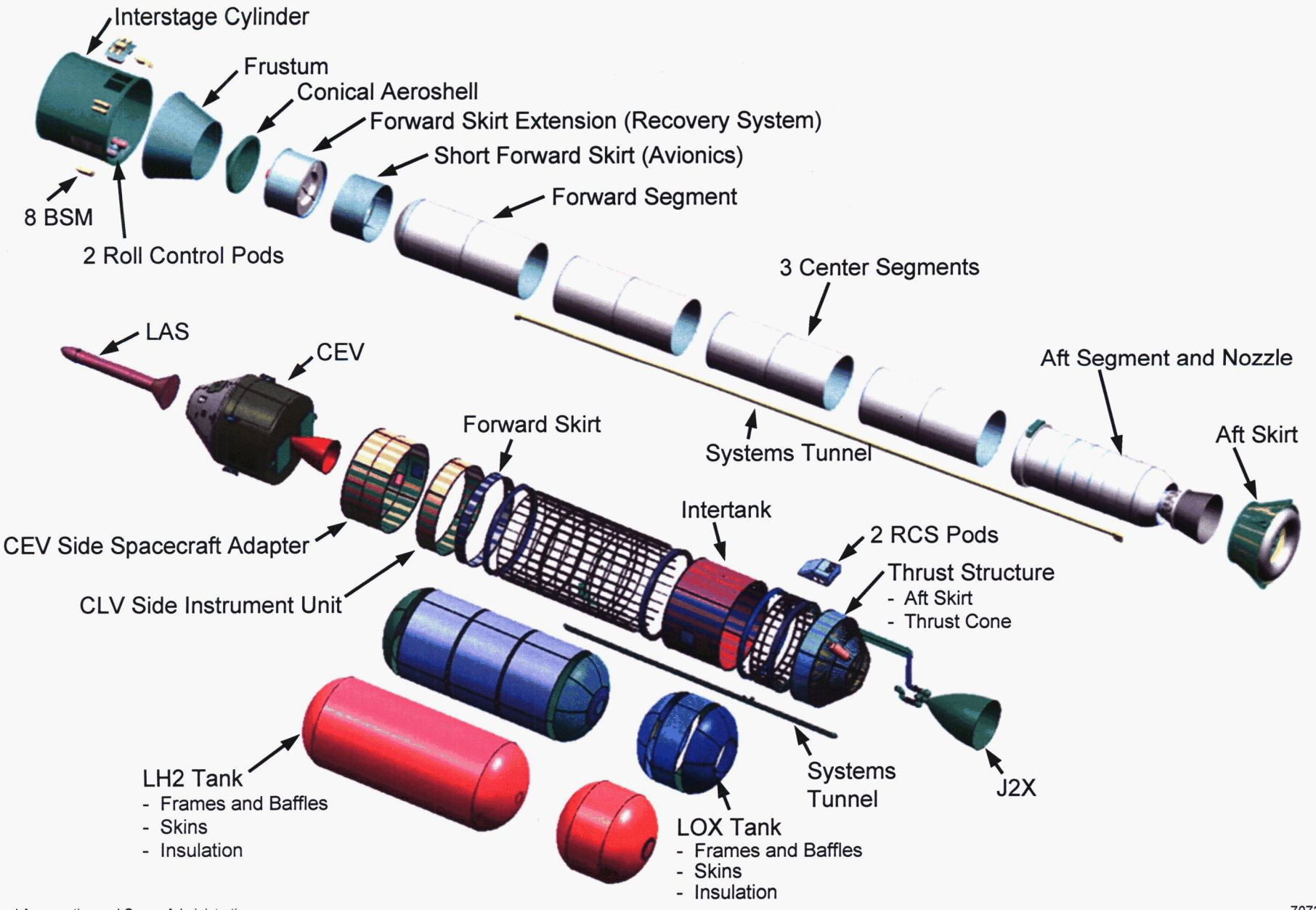
♦ ***NASA – Led Development, Test and Verification***

♦ ***Contracted Production and Operation Support***

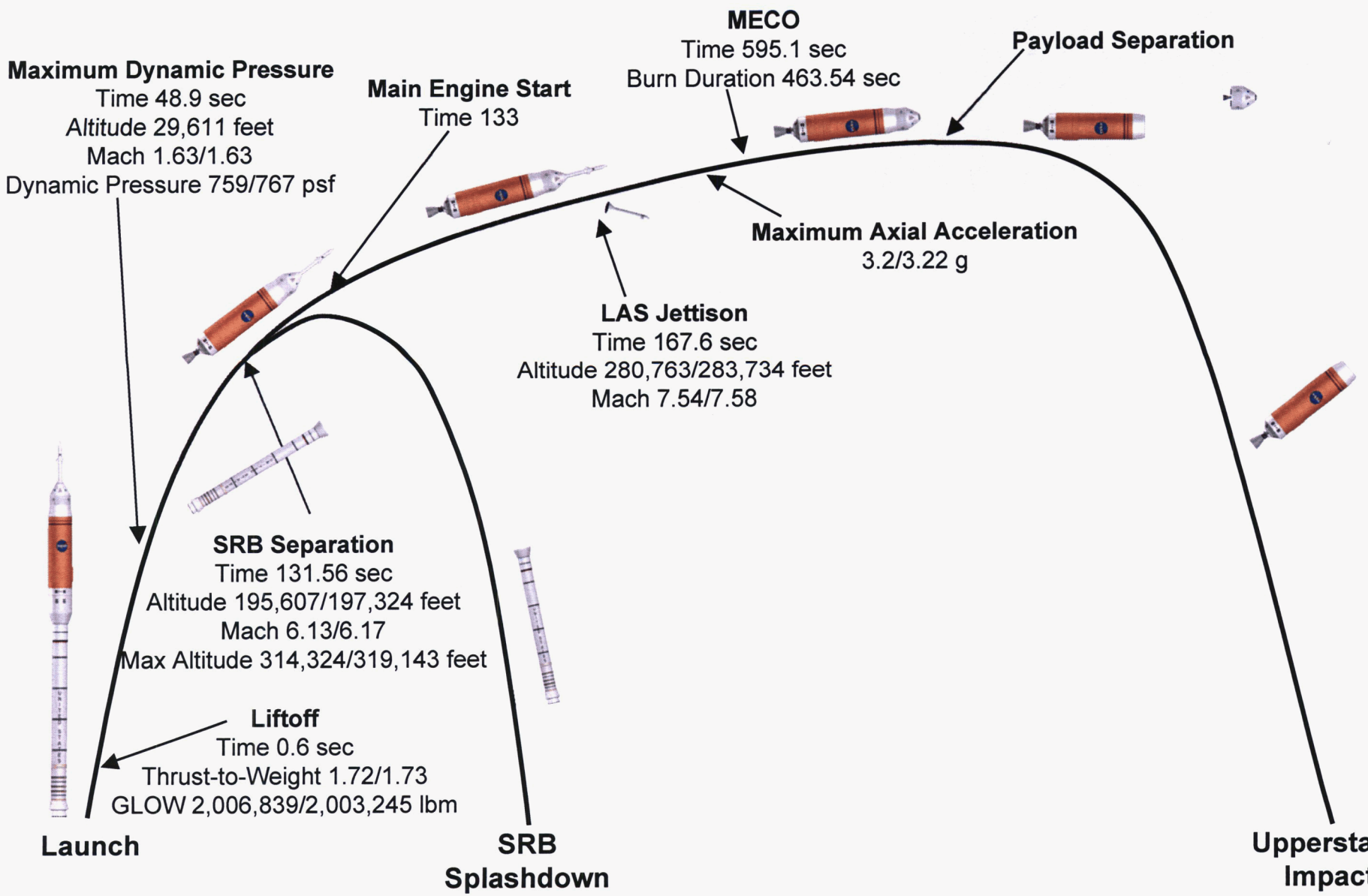
Upper Stage Engine

- Saturn J-2 derived engine (J-2X)
- Expendable

CLV Configuration – Expanded View

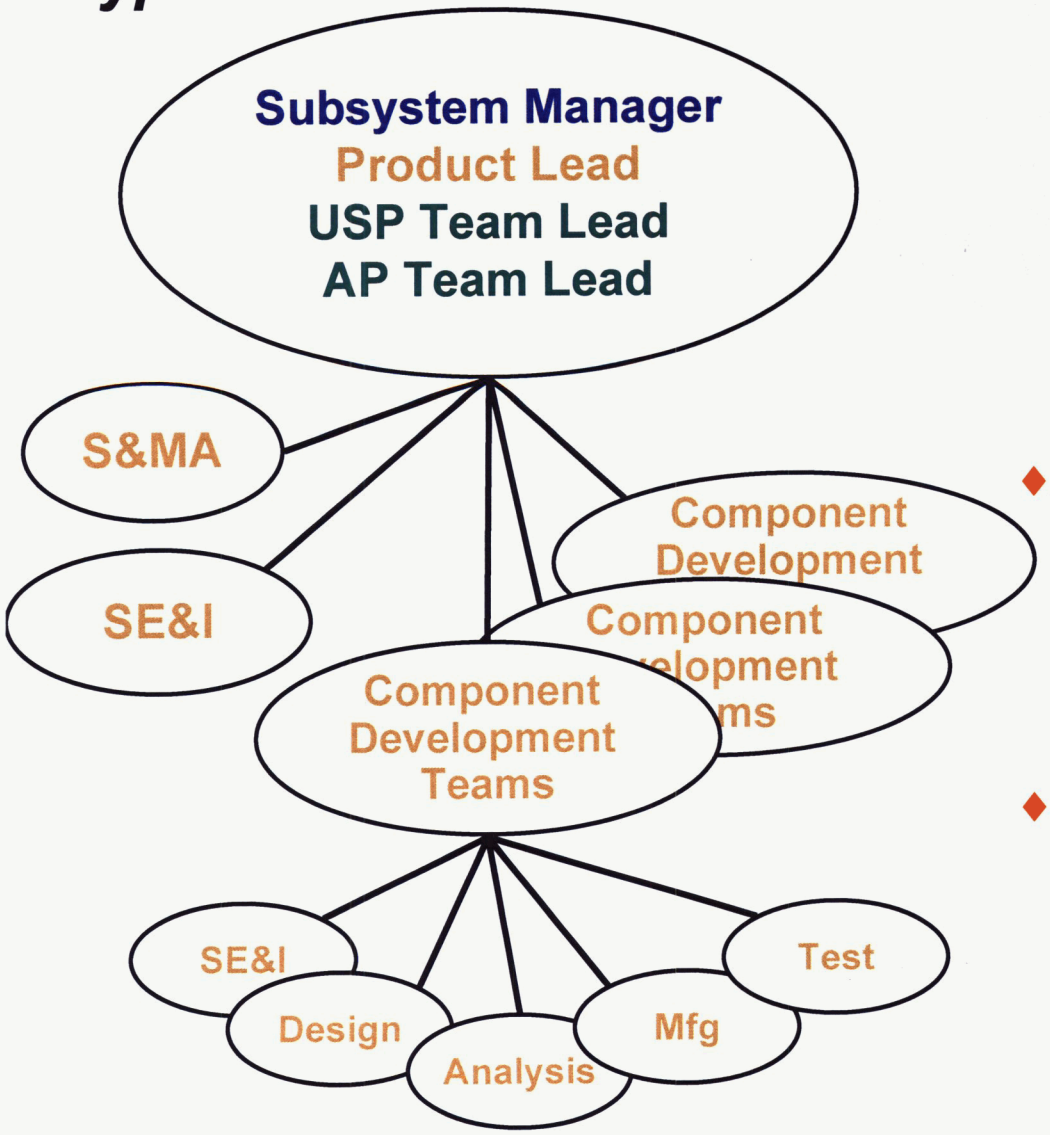


Reference Missions (28.5°/ 51.6°)



NASA Design Team (NDT) IPT Structure

Typical IPT



SSM - Strategic Responsibility Staffed by Project

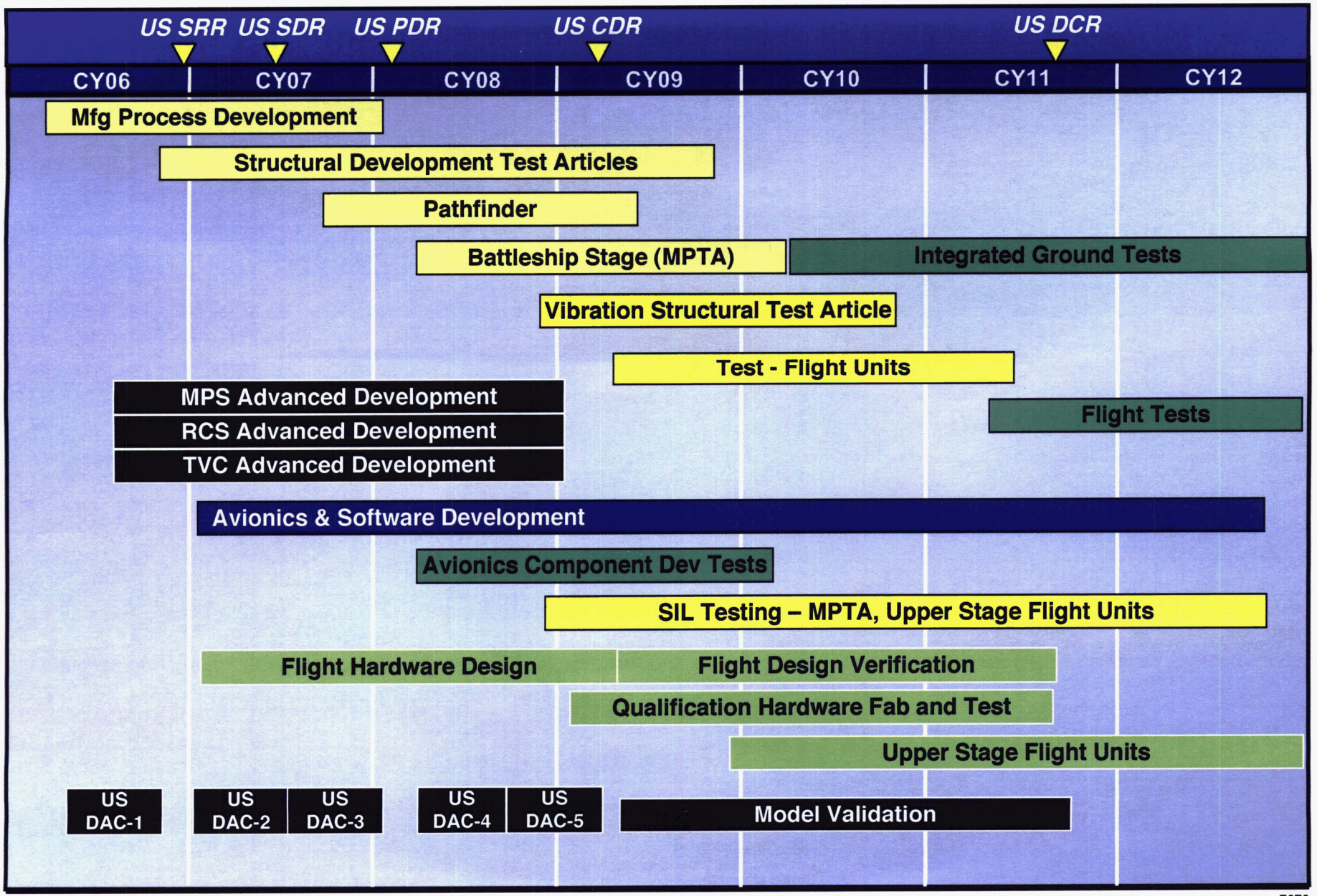
PM - Tactical Responsibility Staffed by Engineering

Upper Stage Production (USP) Lead - Production and Ops Responsibility

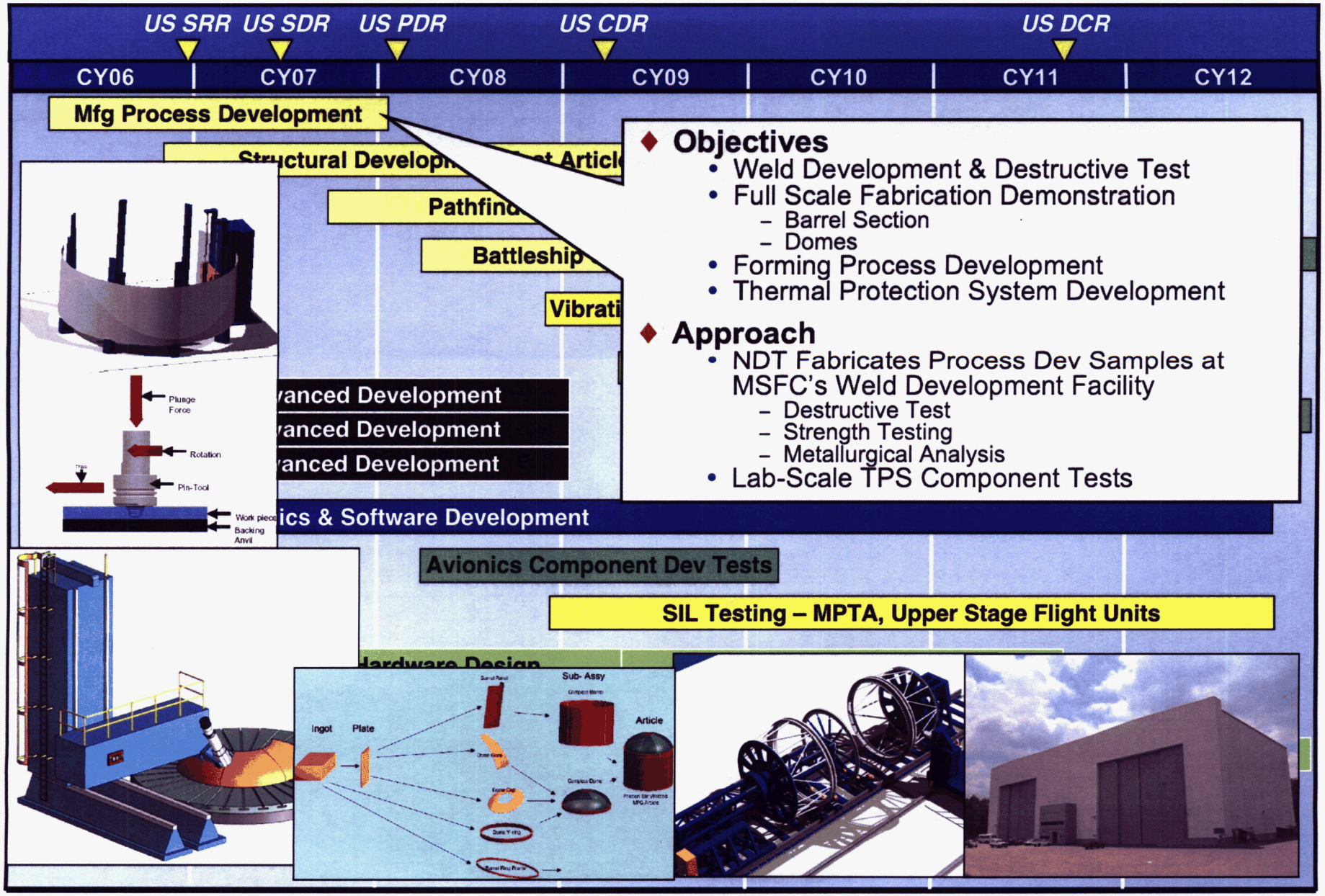
Avionics Production (AP) Lead – Production and Ops Responsibility

- ***Approach***
  - *Early Participation of NASA Contractors in a collaborative environment*
  - *No-Nonsense Design*
    - *Limit Requirement Creep / Over Specification*
    - *Proven Technology*
- ***Goals***
  - *Safe Design – First and Foremost*
  - *Reduce Cost*
    - *Robust Design – Easy to Operate and Maintain*
    - *Lean Manufacturing*
    - *Minimize Logistics Footprint*
  - *Performance and Value*

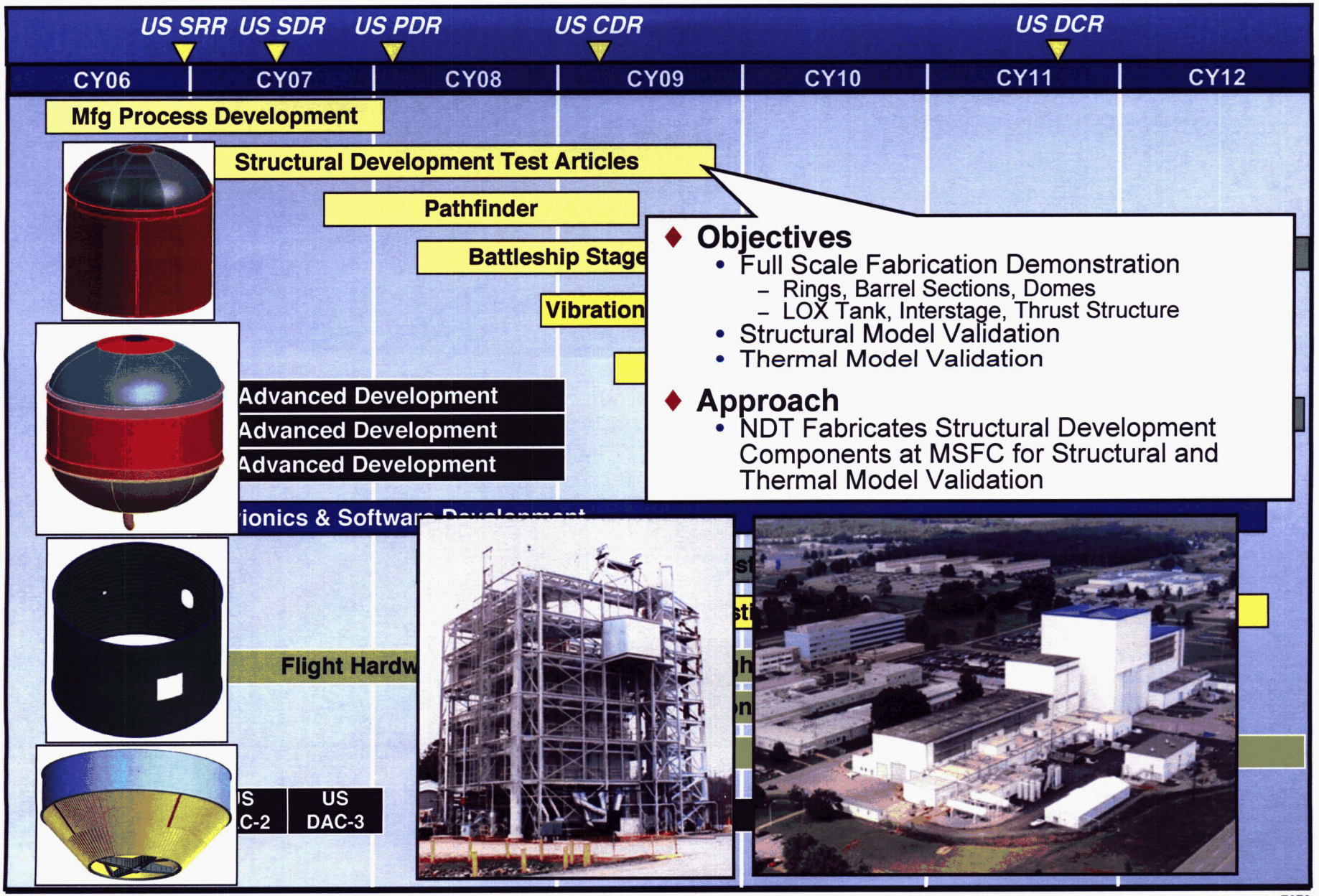
Upper Stage Integrated Roadmap



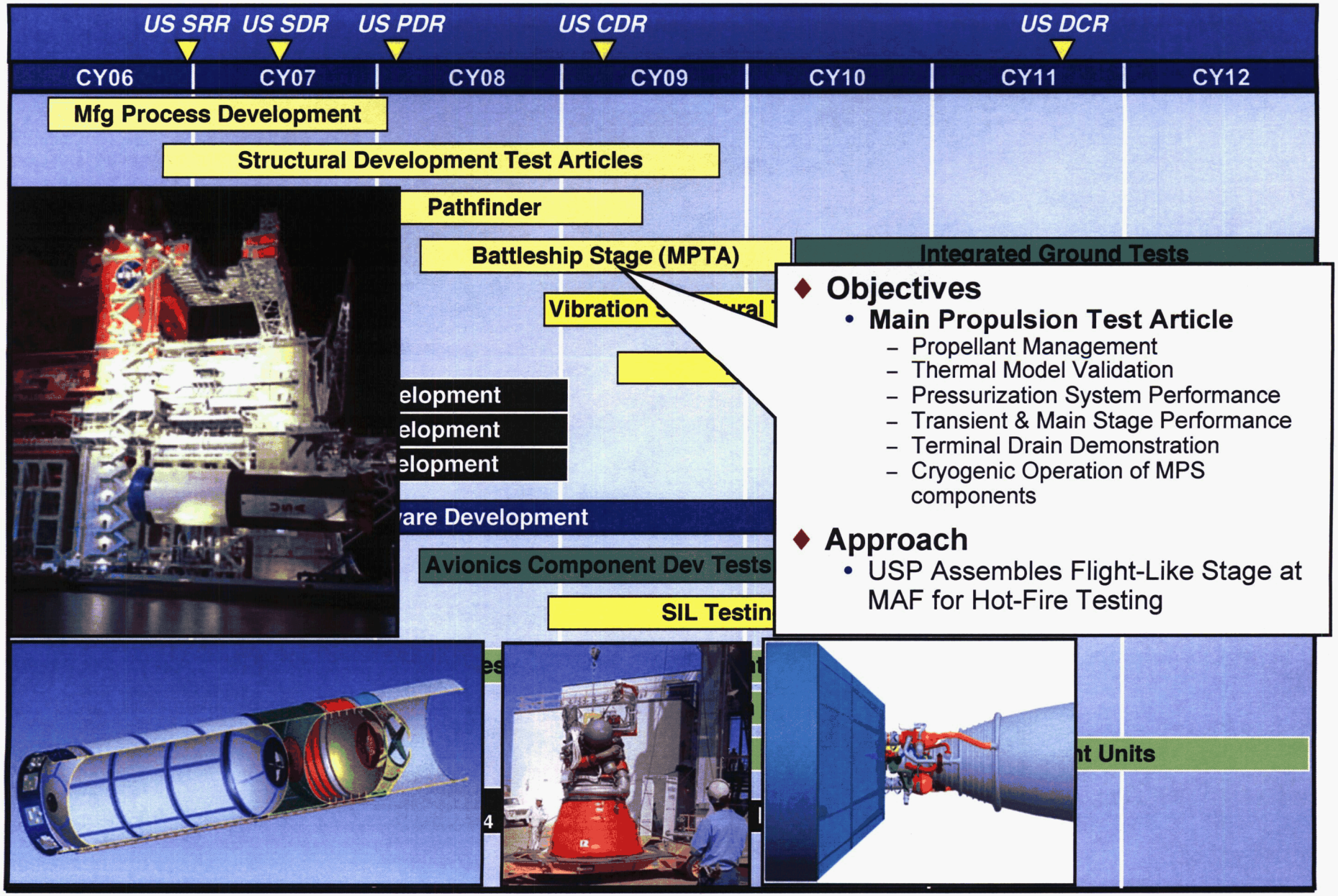
Manufacturing Process and Tooling Development



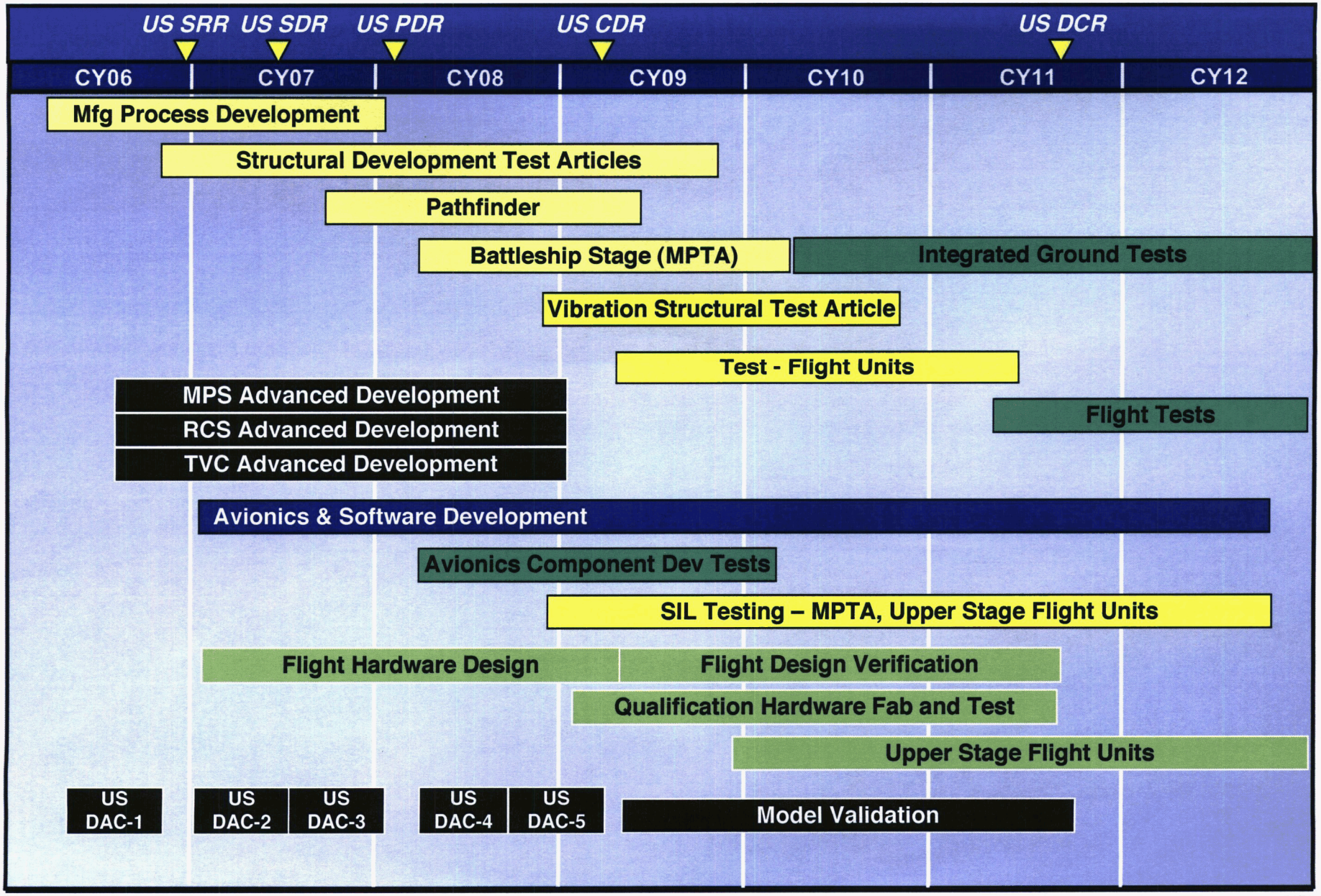
Structural Development Test Article(s)



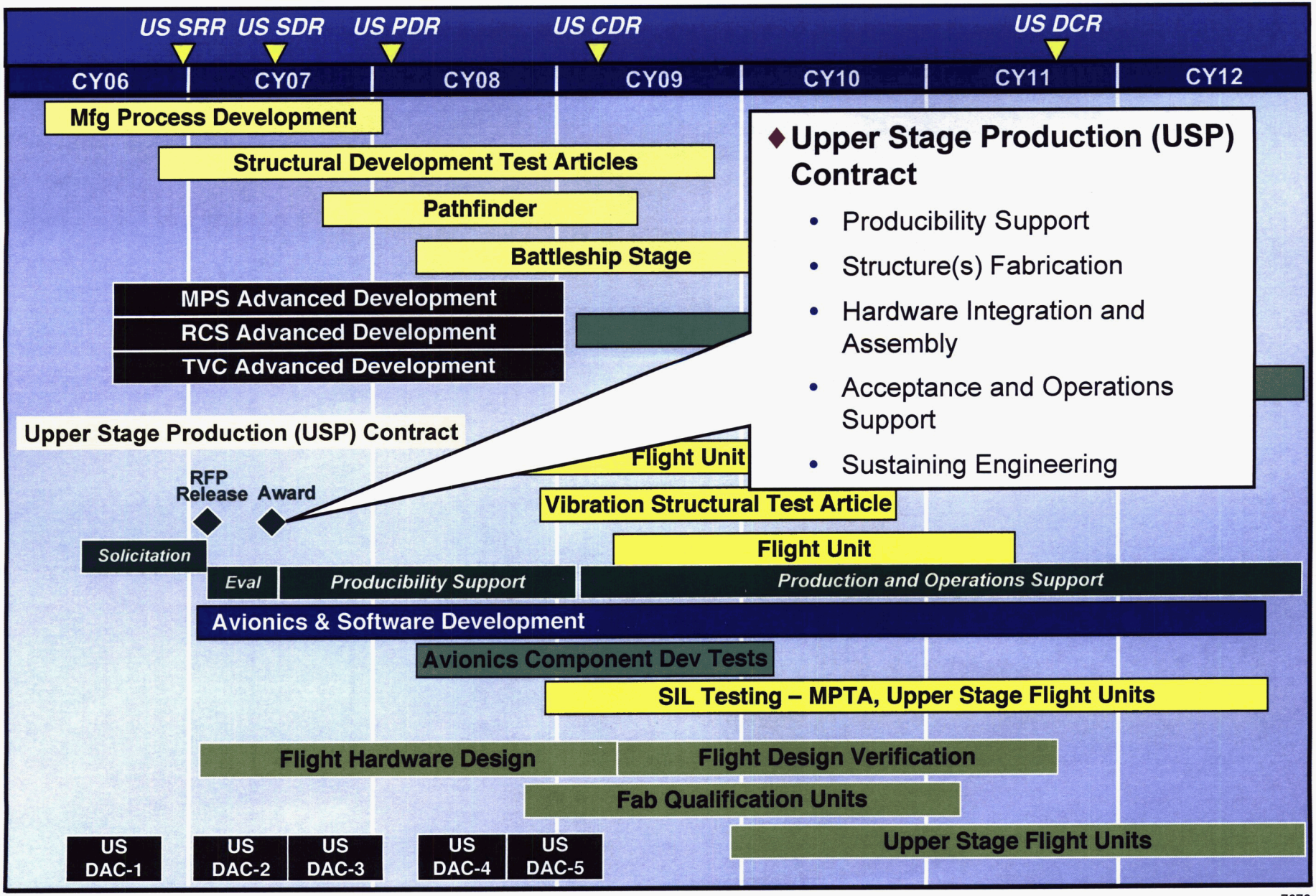
Battleship Stage



Upper Stage Integrated Roadmap



Upper Stage Integrated Roadmap



Upper Stage RFI Summary

- **21 Companies / Teams Responded to the Upper Stage RFI**

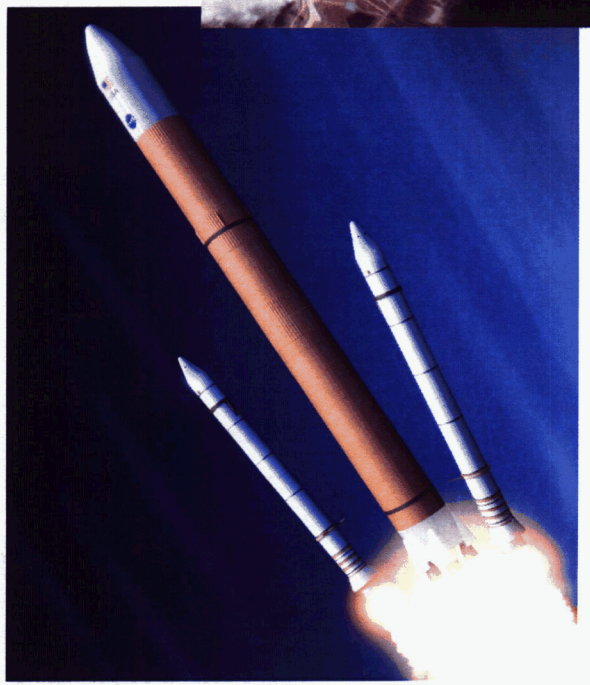
- **Summary of responses:**
  - Supportive of NASA Design Team Approach
  - Supportive of separating USP and AP
  - Recommend Early Industry Involvement
    - Integrated Product Team Approach
    - Early technical reviews with Industry
    - Early study contracts
    - "Badge-less" workforce in a collaborative environment
  - Incorporate USP Configuration Management Early
    - Single Authoritative Data Repository
  - Establish and Baseline the Upper Stage Processes and Standards early with IPT Support
  - Develop "Buy To" Packages
  - Management/contracting of sub-systems and components
  - Multiphase Contract Approach
    - Cost type migrating toward fixed price production

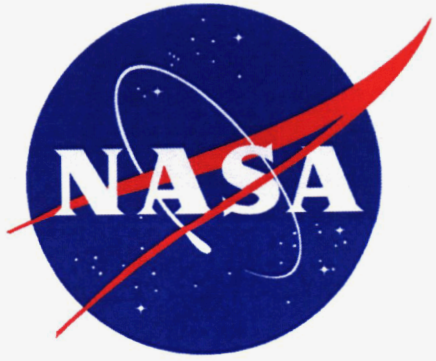
Upper Stage - Path Forward

- **Finalize Acquisition Strategy**
  - Complete detailed RFI input review
  - Acquisition Strategy Meetings to finalize our approach and obtain approval
  - Advanced Development Acquisitions
- **Design and Analysis Cycle**
  - System Requirement Review supports RFP Specification Development
  - Trade Studies
  - Development Planning
  - Manufacturing Plan
- **Project Planning**
  - Integrated Master Schedule
  - Management and Assessment Plan
- **Industry Day Charts will be posted on NAIS Web site at the RFI location:**
  - http://prod.nais.nasa.gov/cgi-bin/eps/bizops.cgi?gr=D&pin=62
  - Updates will be posted as the process continues
  - Question regarding the Upper Stage Procurements can be sent to Earl Pendley at 256-544-2949 or email to george.e.pendley@nasa.gov
- **The Acquisition approaches discussed are pre-decisional**

Summary

- Build beyond our current capability to ferry astronauts and cargo to low Earth orbit.
- Steps will be evolutionary, incremental, and cumulative.
- To reach for Mars and beyond we must first reach for the Moon.
- Team is on board and making good progress.
- Utilizing extensive lessons learned to minimize cost, technical, and schedule risks.





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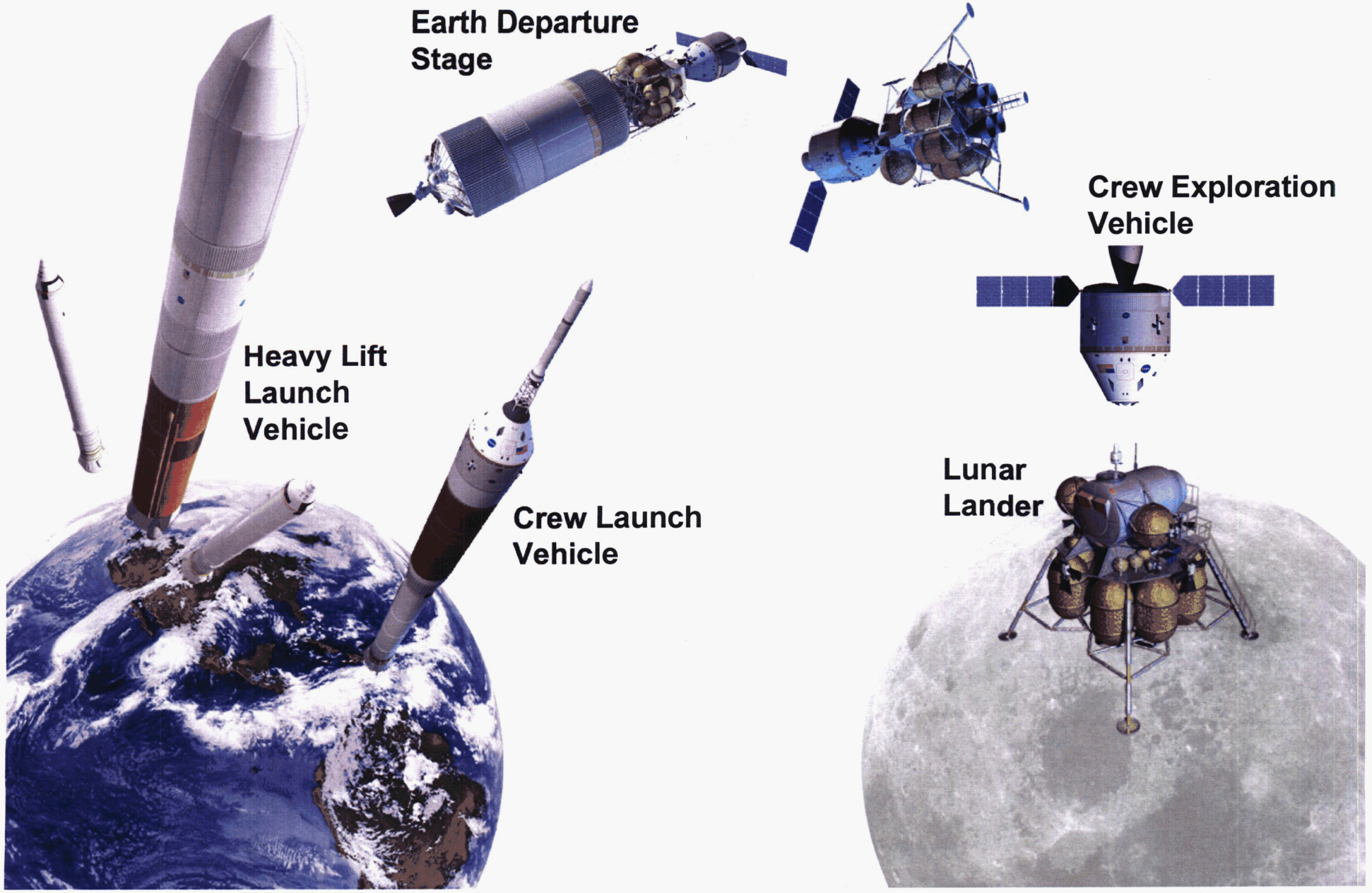
Components of Program Constellation



Constellation Launch Vehicle Elements

LAS

Crew Exploration Vehicle (CEV)
(Crew Module / Service Module)

Instrument Unit

Spacecraft Adapter

Forward Skirt

Upper Stage

J-2X Upper Stage Engine

Interstage

Forward Frustum

First Stage
(5-Segment Reusable Solid
Rocket Booster (RSRB))

Crew Launch Vehicle

Composite Shroud

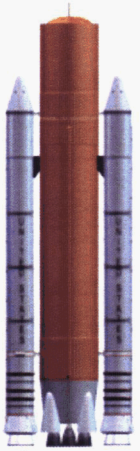
Ascent Stage

Descent Stage

} LSAM

EDS Stage
LOx/LH2
One J2S+ Engine
Al-Li Tanks/Structures

Interstage

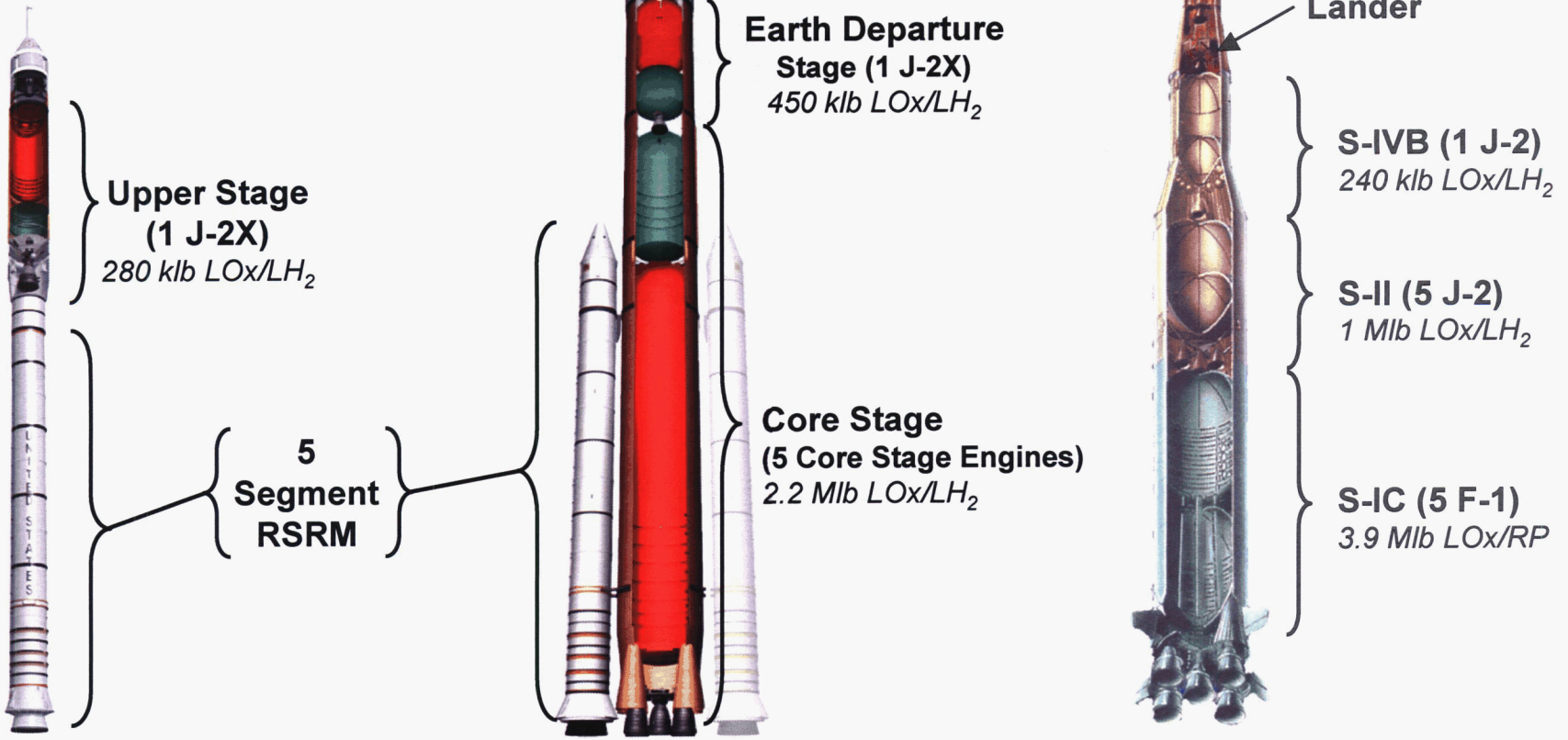


Core Stage
LOx/LH2
Five RS-68 Engines
Al-Li Tanks/Structures

Two 5-Segment RSRBs

Cargo Launch Vehicle

Launch Vehicle Comparison



Height: *309 ft*
Gross Liftoff Mass: *2.0Mlb*

55 klbm to LEO

Crew Launch Vehicle

Height: *358 ft*
Gross Liftoff Mass: *6.4Mlb*

121 klbm to Trans-Lunar Injection
147 klbm to TLI in Dual Launch Mode with CLV

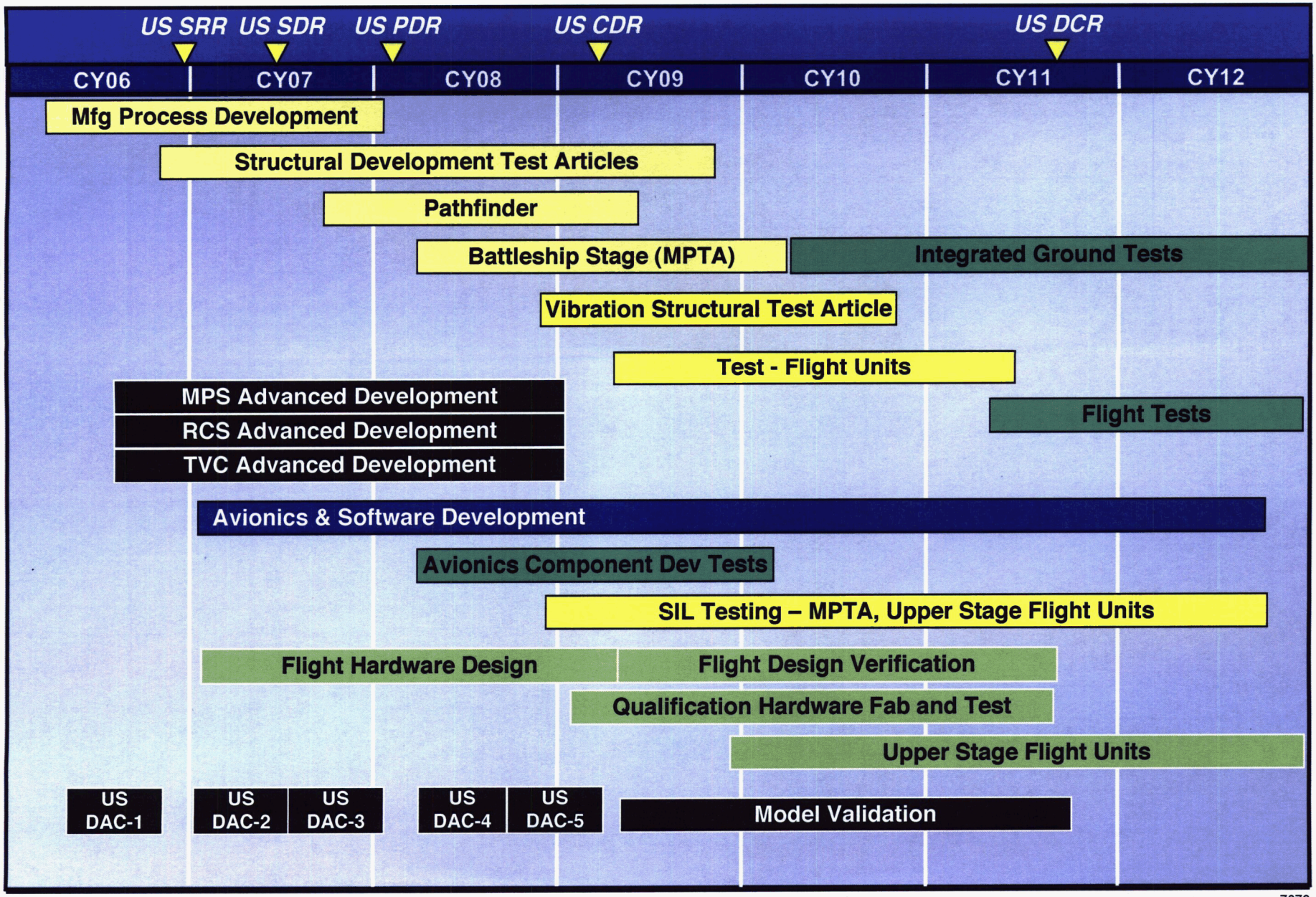
Cargo Launch Vehicle

Height: *364 ft*
Gross Liftoff Mass: *6.5Mlb*

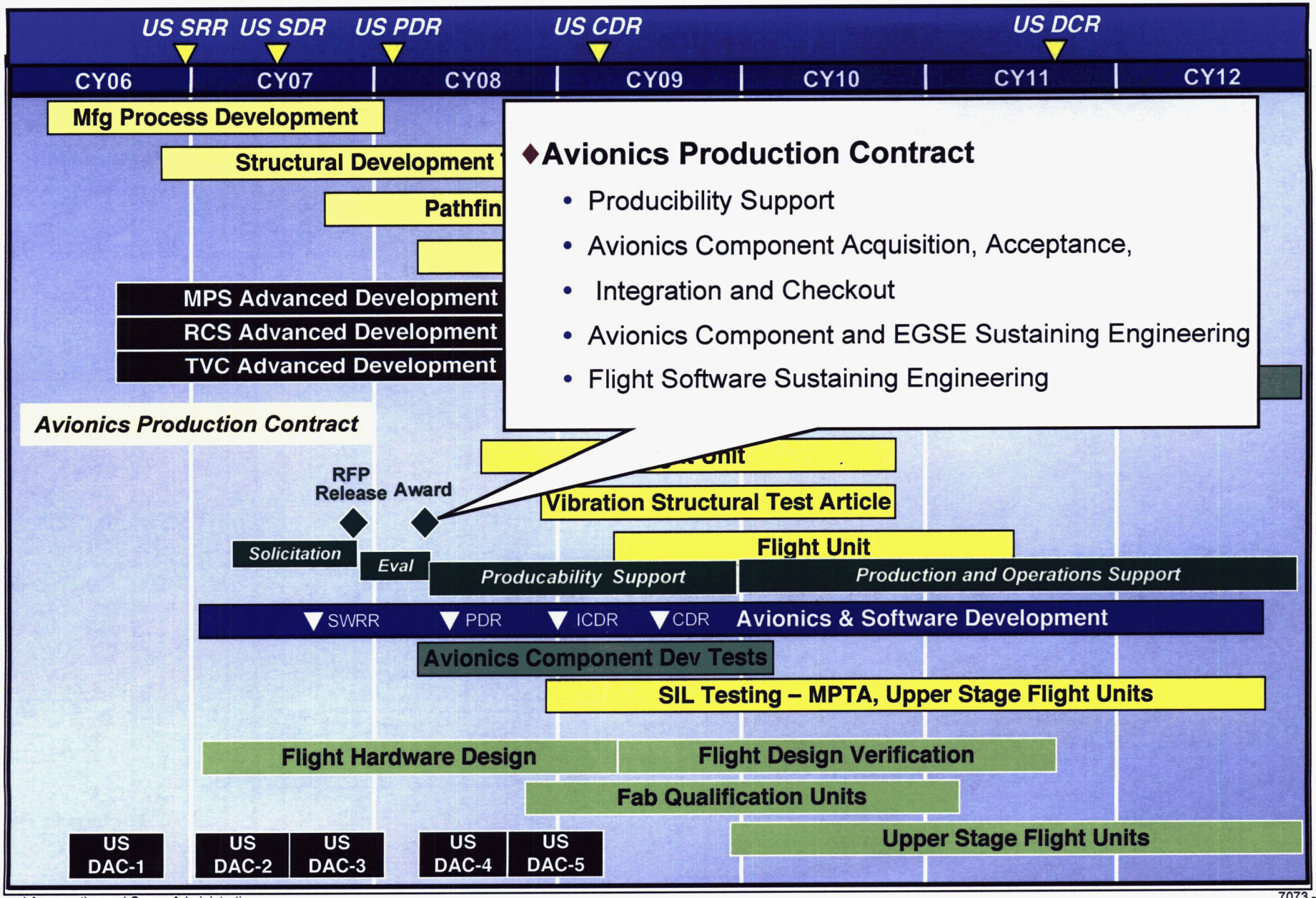
112 kblm to Trans-Lunar Injection

Saturn V

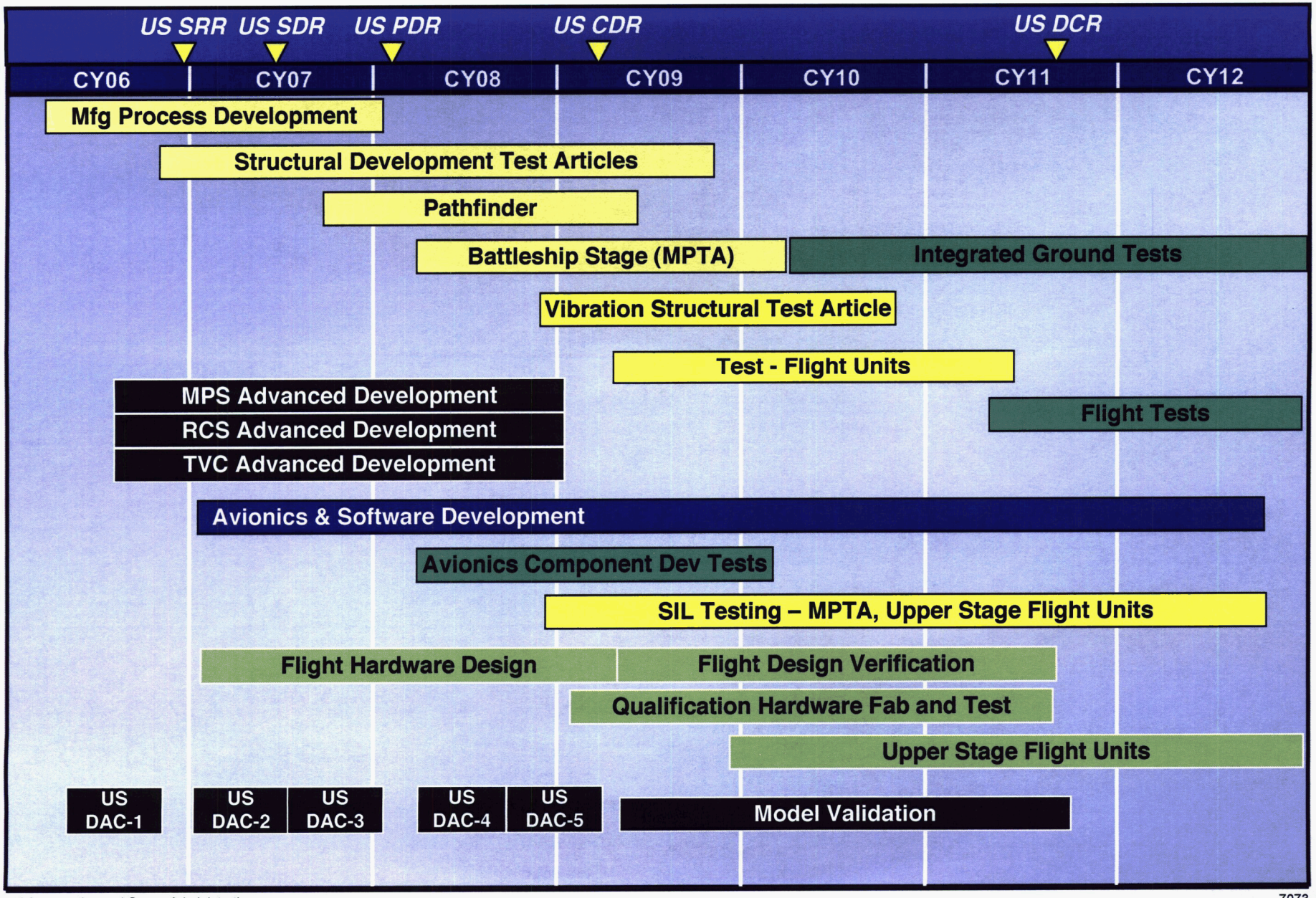
Upper Stage Integrated Roadmap



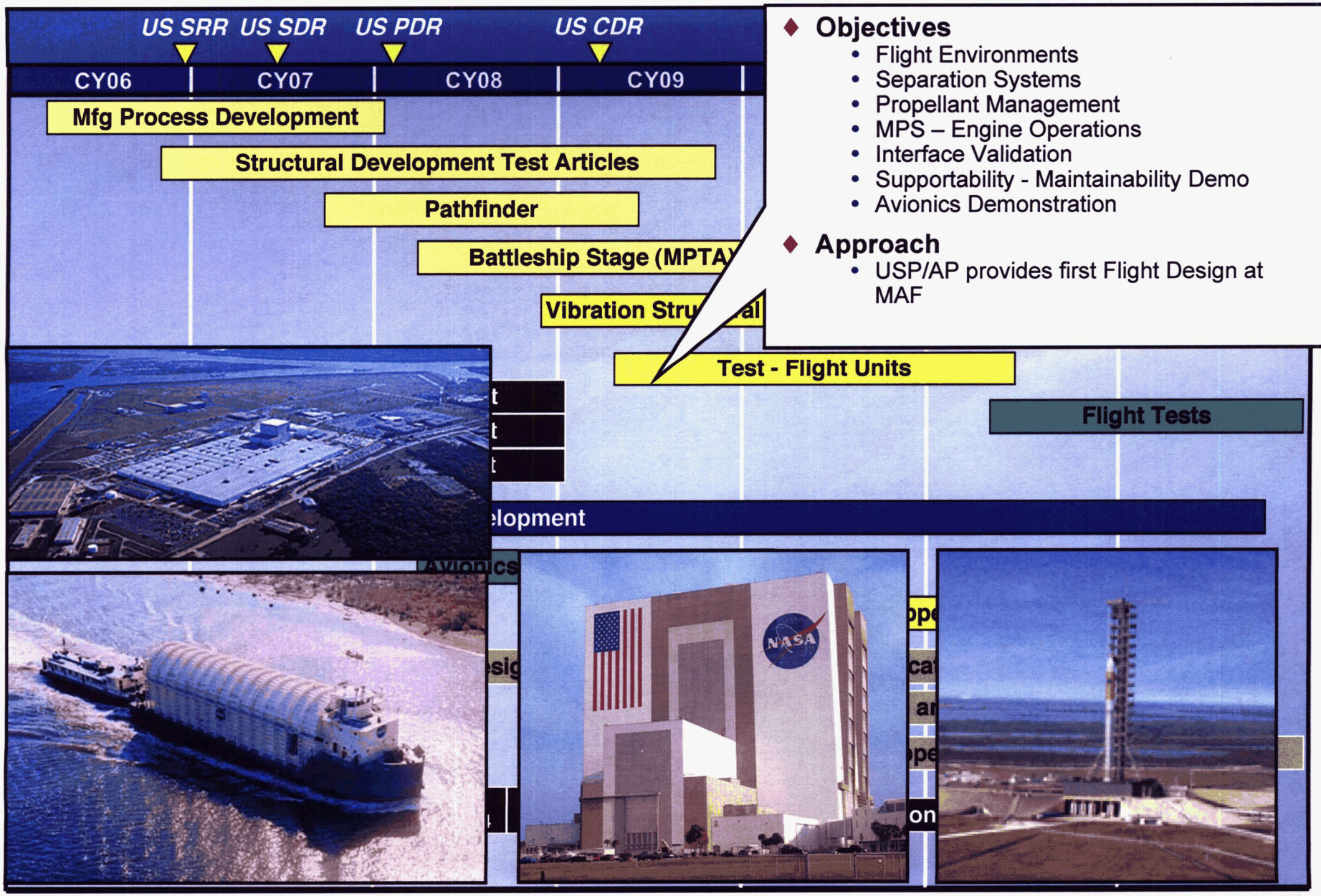
Upper Stage Integrated Roadmap



Upper Stage Integrated Roadmap

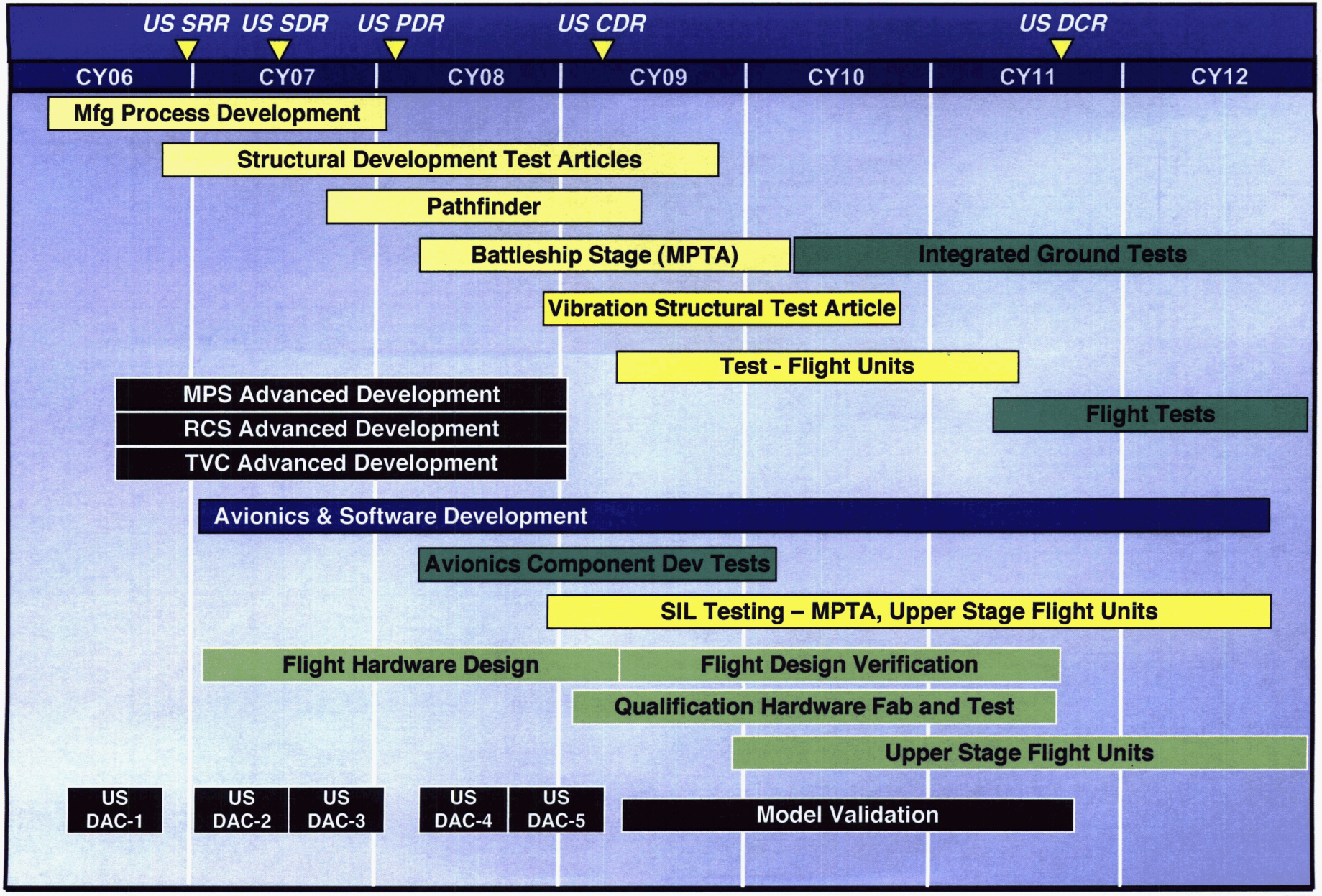


Flight Test Article(s)

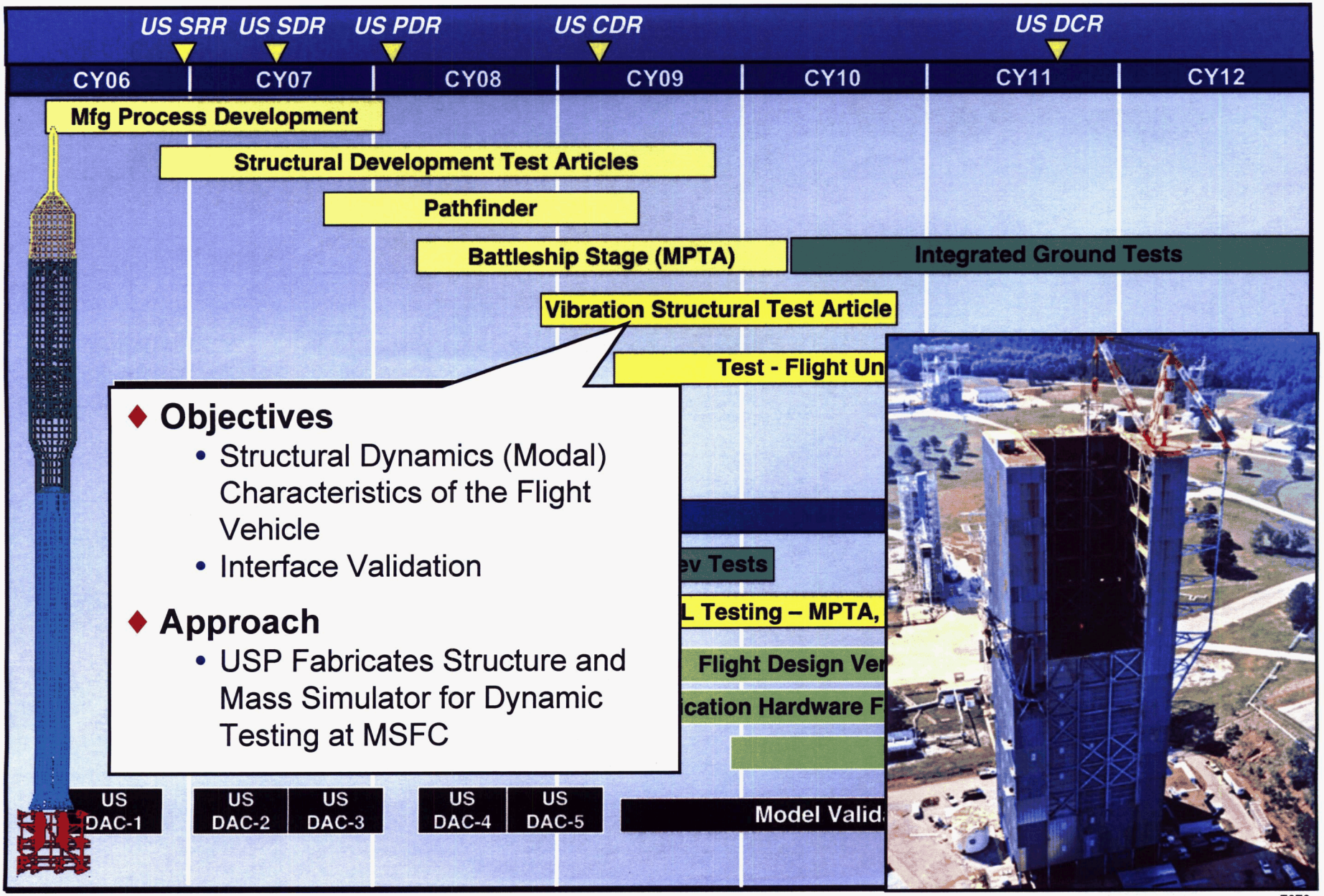


- **Objectives**
  - Flight Environments
  - Separation Systems
  - Propellant Management
  - MPS – Engine Operations
  - Interface Validation
  - Supportability - Maintainability Demo
  - Avionics Demonstration
- **Approach**
  - USP/AP provides first Flight Design at MAF

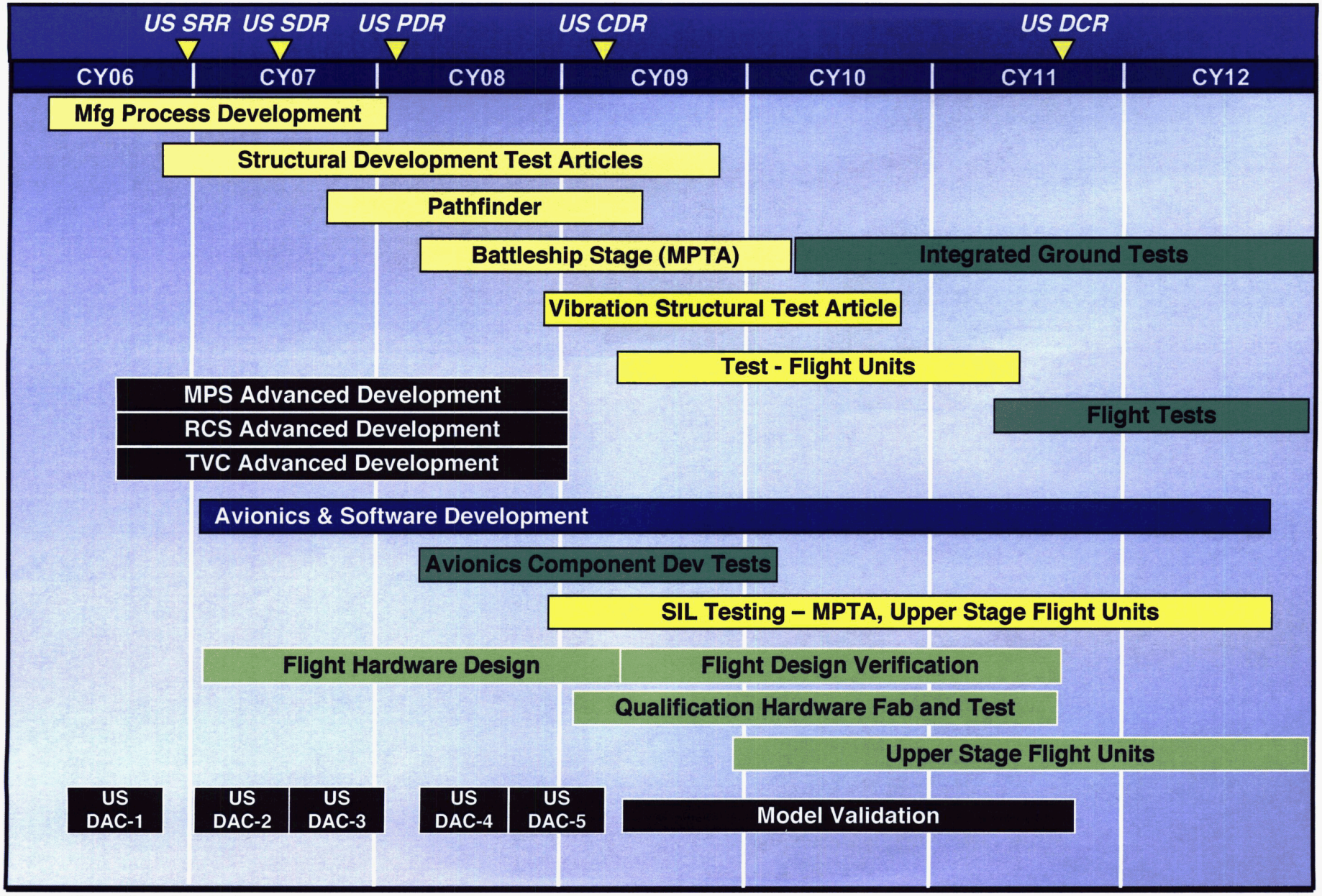
Upper Stage Integrated Roadmap



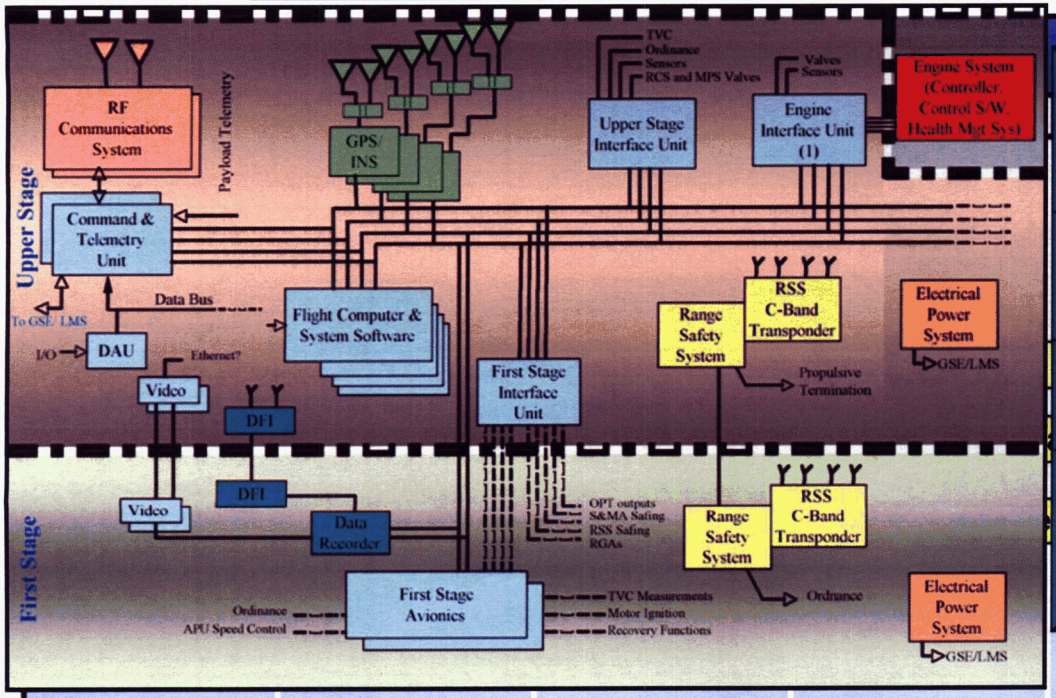
Ground Vibration Test Article(s)

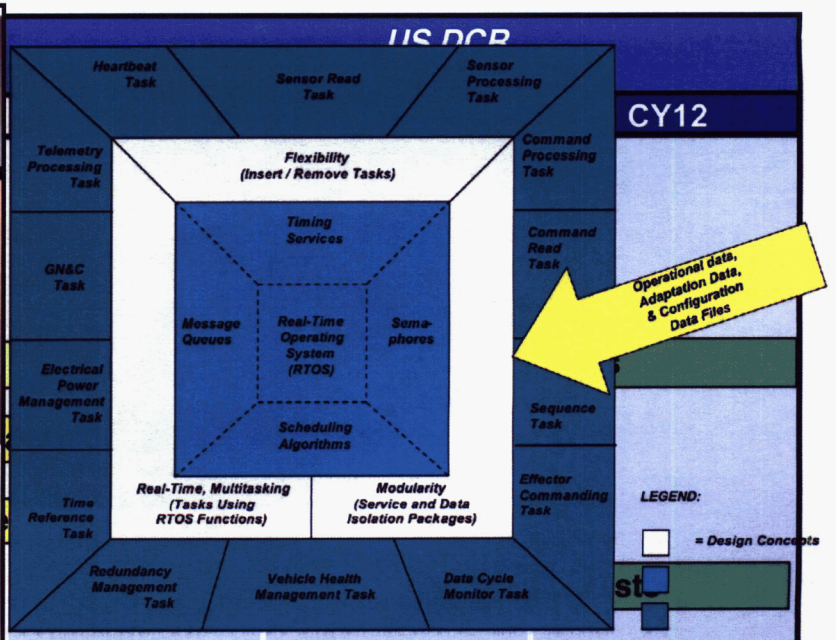


Upper Stage Integrated Roadmap



Integrated Avionics & Software Testing





Avionics & Software Development

Avionics Compon t Dev Tests

SIL Testing – MPTA, Upper Stage Flight Units

Qual es

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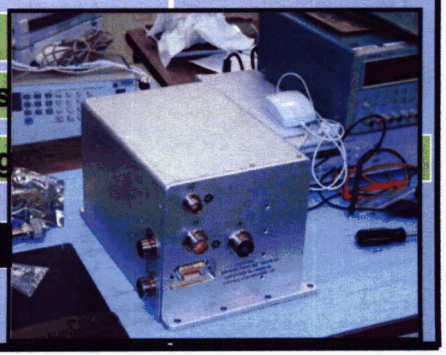
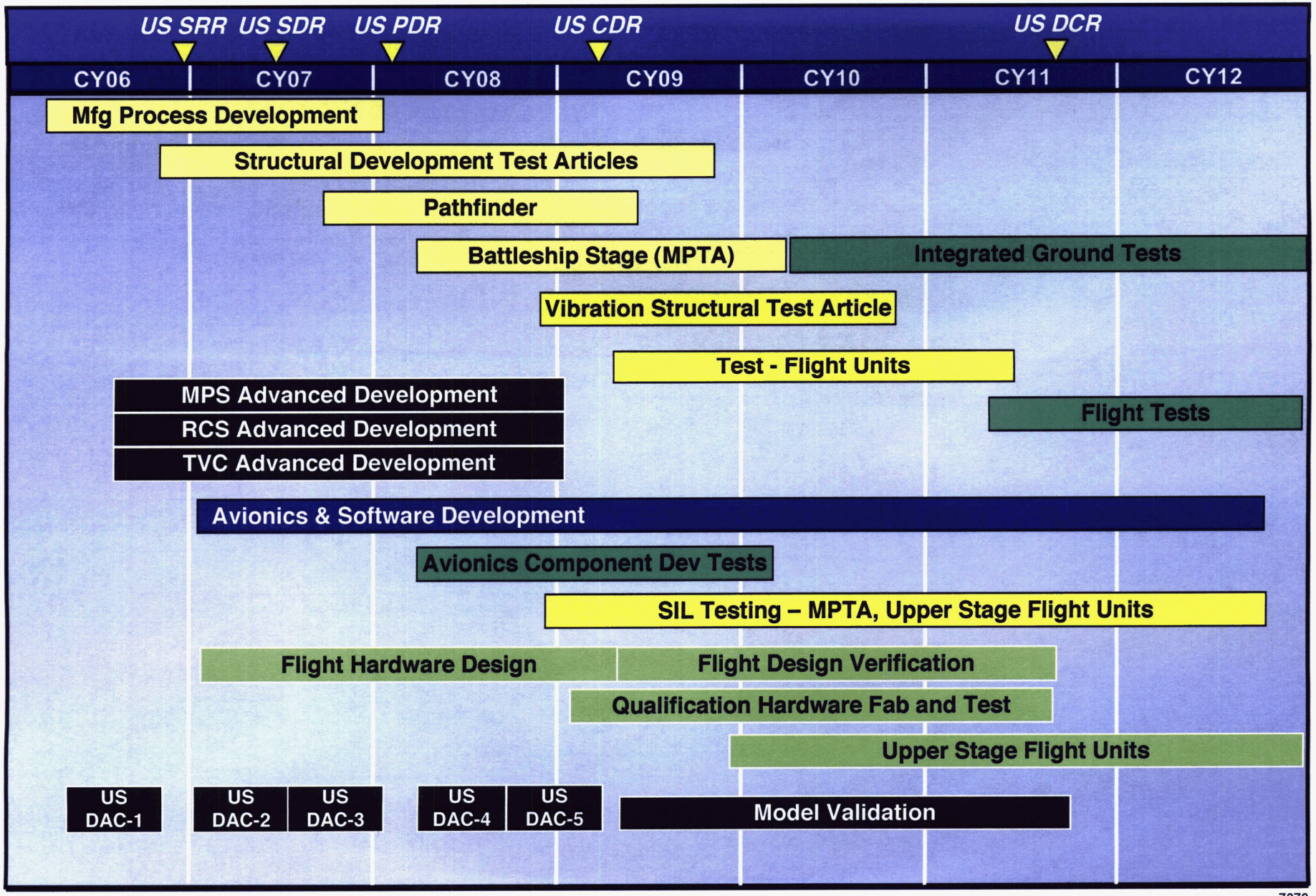
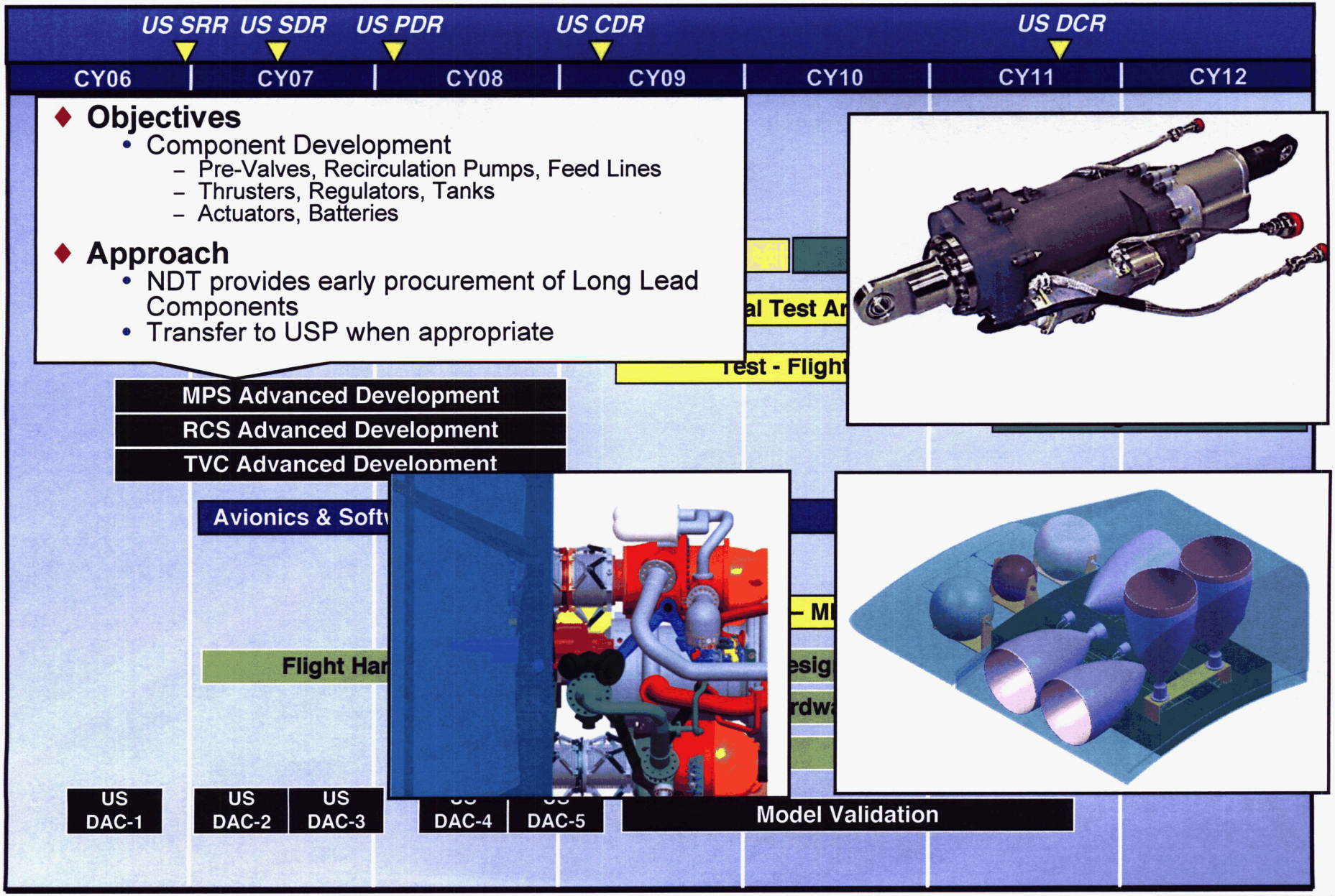


- **Objectives**
  - Avionics Development and Certification
  - Software Development and Certification
- **Approach**
  - NDT provides early components for system build-up and test
  - AP provides Flight units for test and integration

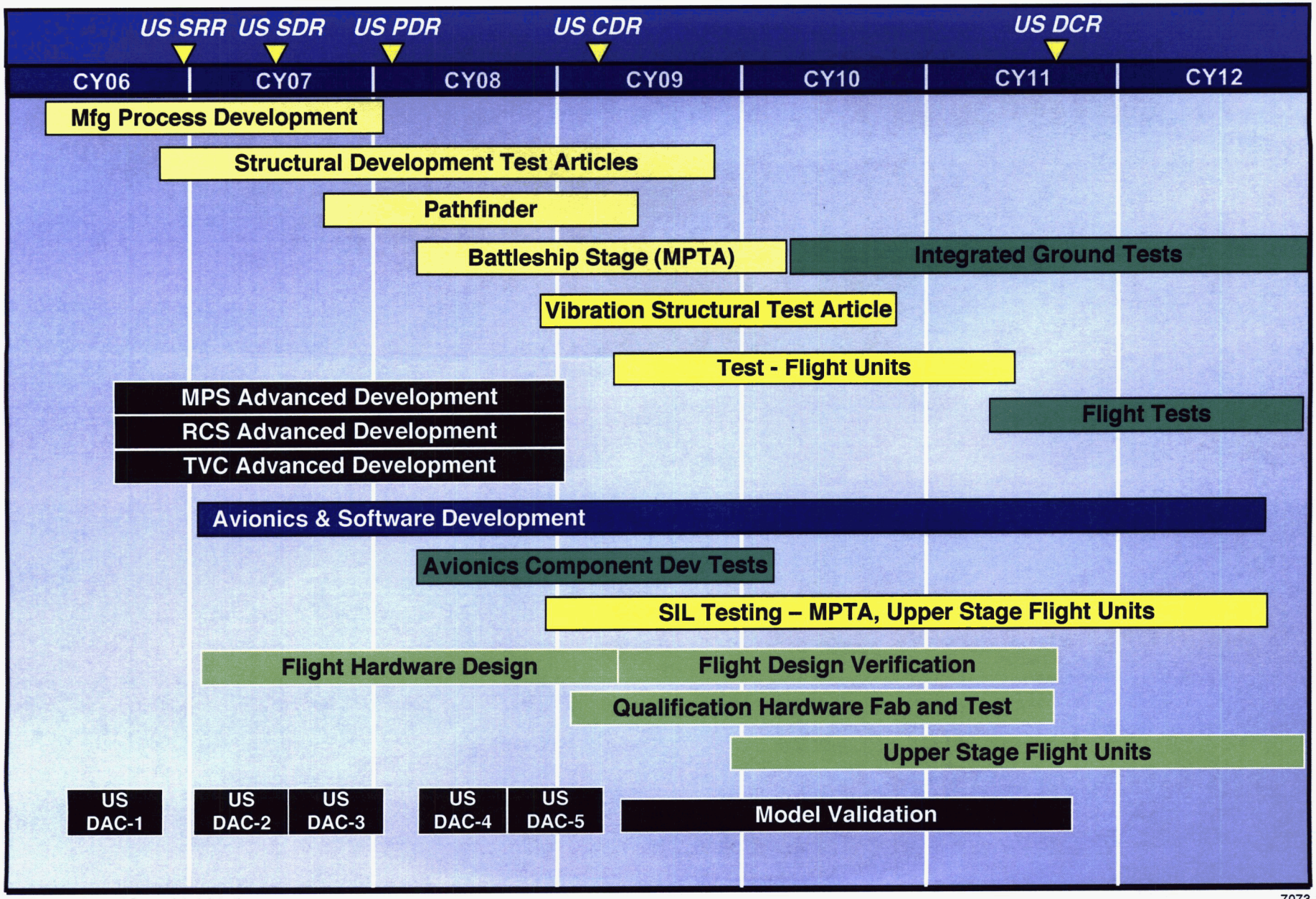
Upper Stage Integrated Roadmap



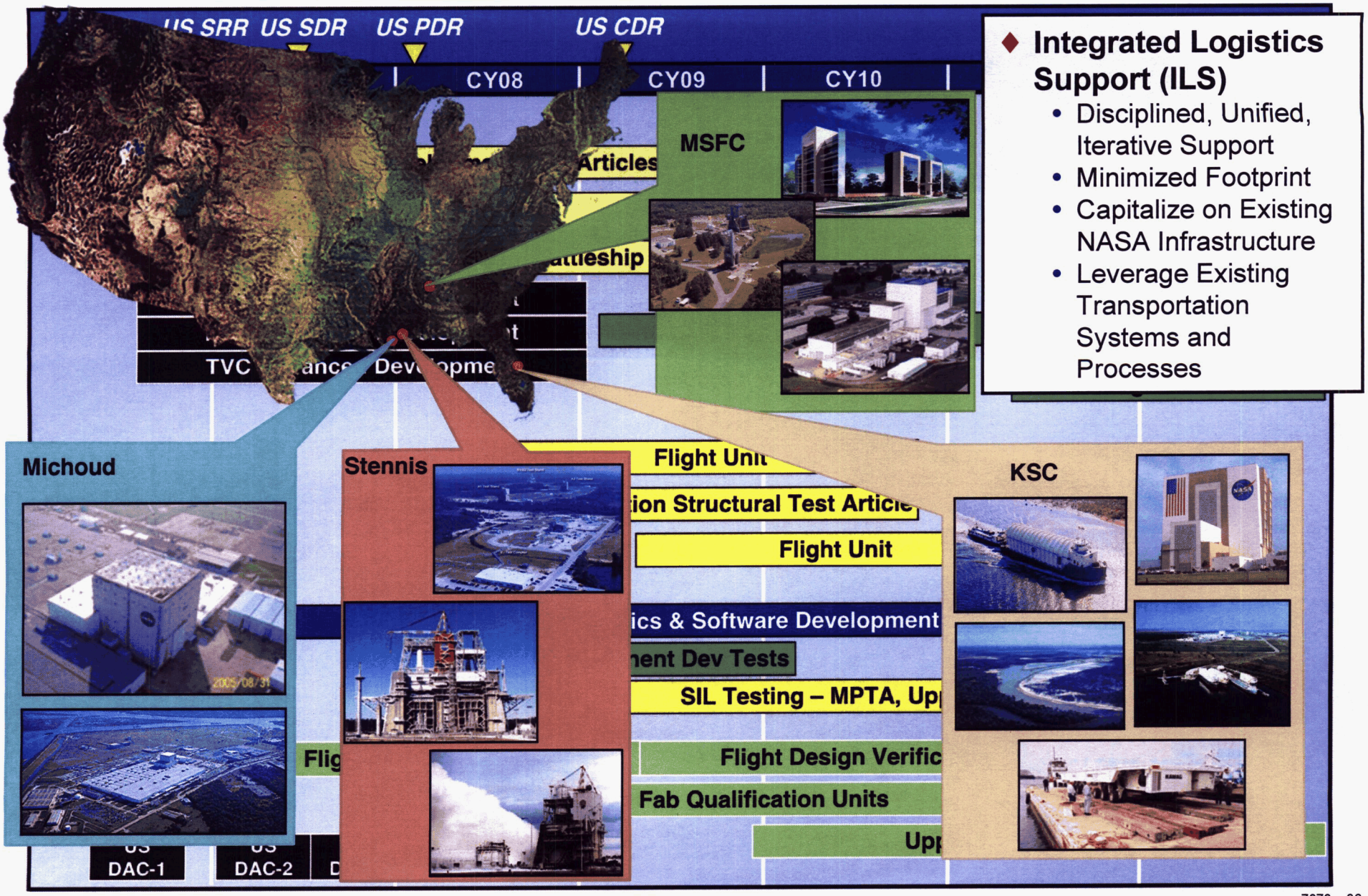
Advanced Development(s)



Upper Stage Integrated Roadmap

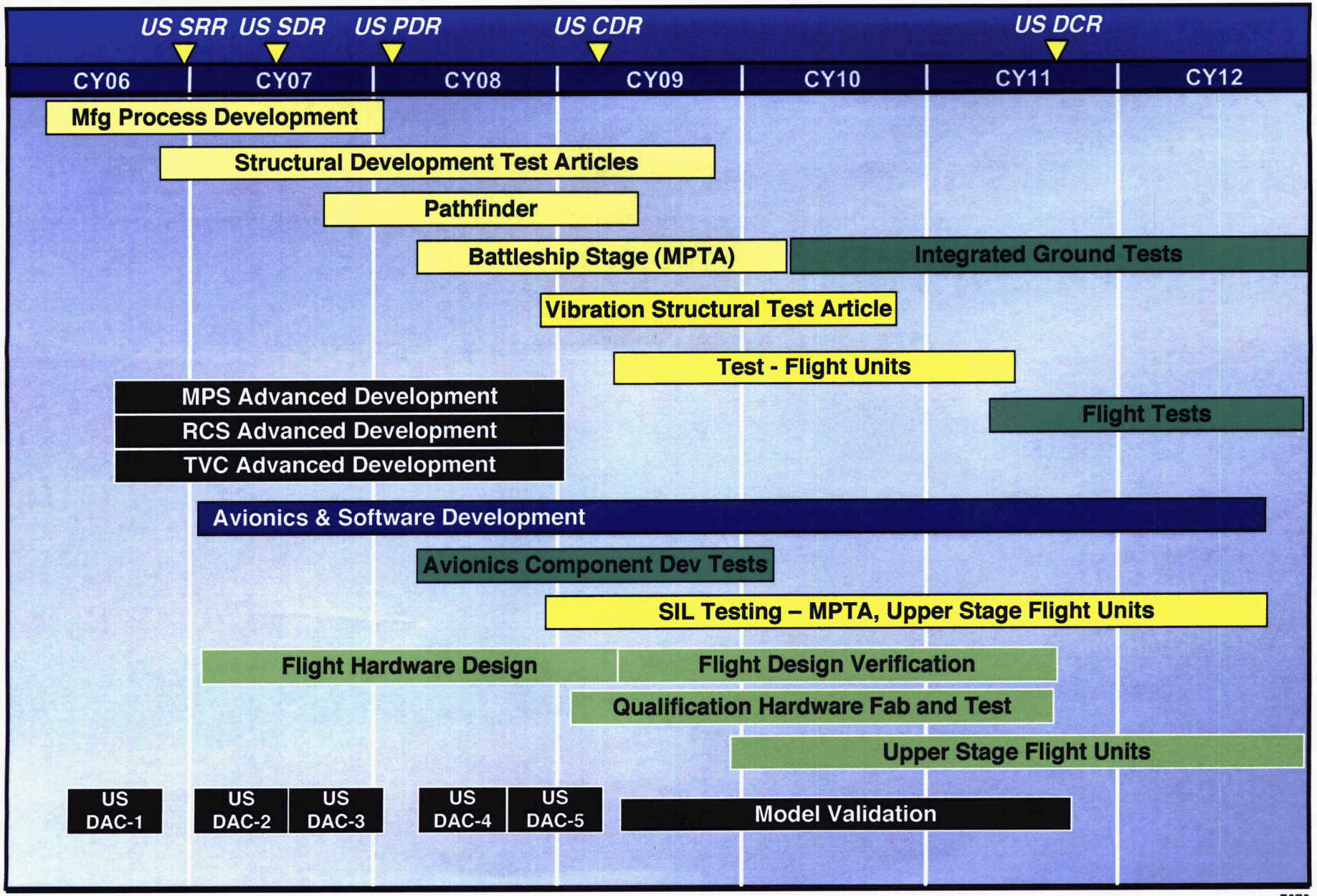


Upper Stage Integrated Logistics



- **Integrated Logistics Support (ILS)**
  - Disciplined, Unified, Iterative Support
  - Minimized Footprint
  - Capitalize on Existing NASA Infrastructure
  - Leverage Existing Transportation Systems and Processes

Upper Stage Integrated Roadmap



Upper Stage Integrated Roadmap